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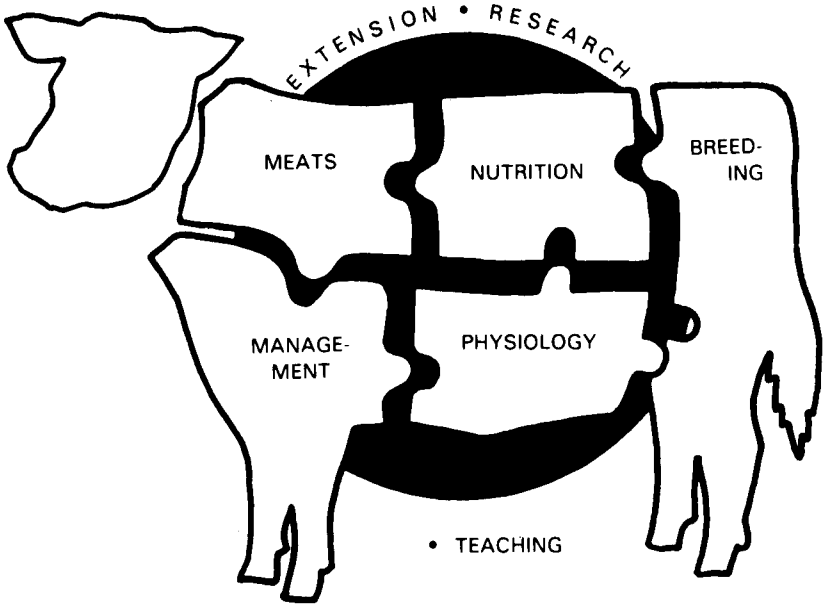
1998 Nebraska Beef Cattle Report

NEBRASKA



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Spring versus Summer Calving for the Nebraska Sandhills: Production Characteristics

Greg Lardy
Don Adams
Dick Clark
Terry Klopfenstein
Jackie Johnson
Andy Applegarth[1]

Summer calving reduced hay inputs necessary to maintain the cow herd by 1.5 tons/cow/year.

Summary

Effects of summer calving versus traditional spring calving were investigated over three years. Calving dates were: 1) March to April (beginning March 18) for spring calving and 2) mid-June to mid-August (beginning June 18) for summer calving. Spring-born calves were weaned in October, while summer-born calves were weaned in November or January. Summer calving cows were bred either on native range or subirrigated meadow. Birth weights were higher for summer-born calves, although weaning weights were lower. Pregnancy rates for spring-calving cows bred on native range were similar to summer-calving cows bred on subirrigated meadow or native range. Summer calving reduced the amount of hay necessary to winter the cow herd by about 3,150 lb/hd/year. The amount of supplement fed/cow/year was similar for spring and summer calving cows. Summer calving offers significant feed and labor savings for cow-calf producers.

Introduction

Analysis of herds participating in the Nebraska IRM project indicated feed costs were the largest portion of the total cost of cow-calf production, although these cost varied among herds. In order to increase profitability, producers must either reduce production costs without sacrificing production or increase production without markedly increasing costs.

The major portion of grazing land in the Nebraska Sandhills is native upland range, which is primarily warm-season grasses. These grasses are highest in quality in June, July, and August (1997 Nebraska Beef Report pp. 3-5). Traditional spring calving herds, however, calve in February, March and April in Nebraska, when warm-season grasses are dormant and will not maintain a lactating cow. Cows, therefore, are fed meadow hay and supplement until turnout to grass. Previous research indicates extending winter and/or spring grazing reduces the amount of hay fed and increases profitability (1993 Nebraska Beef Report pp. 5-8). This information led to establishment of the summer calving project.

Key components of the summer calving system include: 1) cows have access to vegetative forage for a short time prior to calving; 2) reduced hay and supplement cost since peak lactation occurs on vegetative forage; 3) reduced calf sickness and death loss during calving since it occurs during a warm, dry time period rather than the late winter/early spring; 4) reduced labor, machinery and fuel inputs associated with feeding hay; and 5) different marketing alternatives for Sandhills ranches, including a backgrounded calf in March or April, a yearling in September or slaughter cattle in January.

The objectives of this research were to: 1) compare the production traits of spring and summer calving herds in the Nebraska Sandhills, including birth and weaning weights and hay and supplement inputs; and 2) evaluate the effect of breeding on subirrigated meadow or native range for summer calving cows. We hypothesized that while November weaning would be beneficial to the lactating cow grazing winter range, January weaning would be best for keeping calf cost low. Spring born-calves were weaned in mid-October.

Procedure

In 1993, a summer-calving herd was initiated at the University of Nebraska-Lincoln's Gudmundsen Sandhills Laboratory. Cows previously maintained in a traditional spring-calving herd were assigned randomly to be bred in September and October for calving between mid-June and mid-August. Approximately 130 cows are maintained in the summer-calving cow herd, while 400

(Continued on next page)

cows are maintained in the spring-calving herd. Each herd is based on MARC II composite breeding (1/4 Angus, 1/4 Hereford, 1/4 Simmental, 1/4 Gelbvieh).

Table 1 shows the production calendars for the spring- and summer-calving herds. Birth weight, weaning weight, pregnancy rate and feed input data from the spring- and summer-calving herds were collected in 1994, 1995 and 1996.

Within the summer-calving herd, two grazing treatments, either native range or subirrigated meadow regrowth, were imposed during the breeding season.

Two weaning date treatments were imposed on the summer-calving herd. Early weaning occurred November 1, while late weaning occurred January 10.

Because replicate spring- and summer-calving herds were not maintained during the winter feeding period, feed inputs are simply reported and not statistically analyzed. Generally, the spring-calving herd was fed hay from January through mid-May. The summer-calving herd was managed on dormant winter range plus supplement throughout the winter. Hay was fed to summer-calving cows only during extremely inclement weather.

Table 1. Production calendar for spring- and summer-calving herds at the Gudmundsen Sandhills Laboratory.

		Summer calving	
	Spring calving	Early wean	Late wean
Calving dates	March 18 - April 18	June 8 - August 8	June 15-August 15
Breeding season	June - July	September-October	September-October
Weaning date	October 10	November 1	January 10

Table 2. Effect of calving and weaning date on birth weight, birth date, and weaning weight (three years).

		Summer calving		
	Spring calving	Early wean	Late wean	Contrast[1]
Birth weight (lb)	90.0	96.4	95.8	1,3
Birth date (Julian date)	90.5	181.6	179.0	1,3
Weaning weight (lb)	471.0	369.8	435.8	1,2,3

[1]Contrasts: 1, Spring vs. Summer Calving; 2, Early vs. Late-Weaned Summer-Born Calves; 3, Late-Weaned Summer-Born Calves vs. Spring-Born Calves.

Table 3. Effect of grazing native range or subirrigated meadow on cow weight change and body condition score change during the breeding season for summer calving cows.

Treatment	Year	Cow Weight Change	Cow BCS Change
Native Range	1994	-10.8	-0.14
Native Range	1995	-23.0	-0.90
Native Range	1996	-27.2	+0.07
Subirrigated Meadow	1994	45.5	+0.09
Subirrigated Meadow	1995	10.7	-0.39
Subirrigated Meadow	1996	97.1	0.08

Results

Birth weights were higher ($P < .01$) for the summer-calving herd compared to the spring-calving herd (Table 2). Although birth weights were greater, we observed less dystocia with the summer-calving cows than the spring-calving cows. In addition, summer-calving cows were checked less frequently during calving than spring calvers. Average birth date for the spring-born calves was March 30; for the summer-born calves the average birth date was June 29. Actual weaning weights were lower for early and late-weaned summer born calves ($P < .01$) compared to spring-born calves. In addition, weaning weights at about the same day of age (i.e. October versus January) were also lower for late-weaned summer-born calves compared to spring-born calves ($P = .06$). Summer-born calves weaned early had lower weaning weights than summer-born calves weaned in January ($P < .05$).

Summer-calving cows were fed 30 lb of hay/cow/year compared to 3,182 lb/cow/year for spring-calving cows. Similar amounts of protein supplement was fed to summer- (131 lb/cow) and spring-calving cows (108 lb/cow) each year. Opportunities for reducing the amount of hay fed to spring-calving herds exist (1993 Beef Report, pp. 3-5). Previous economic analysis of wintering systems for Sandhills cow herds indicated that maximizing winter grazing while minimizing hay feeding resulted in higher profitability (1993 Beef Report, pp. 5-8).

Significant year-by-treatment interactions were detected for cow weight change and cow body condition score change during the breeding season for summer-calving cows bred on subirrigated meadow or native range (Table 3). Generally, cows gained weight while grazing subirrigated meadow and lost weight while grazing native range. Condition score changes were similar and mostly small during the breeding season, except in 1995 when two fall snowstorms adversely affected cow performance. In 1994, no snowfall was recorded during the breeding season and average temperatures were 2.4°F above normal. During September and October, 1995, 24 inches of snow fell and average temperatures were 1.0°F below average.

Calf gains were higher on subirrigated meadow, compared to native range, during the breeding season ($P = .03$; Table 4). Pregnancy rates were similar ($P = .25$).

Pregnancy rates were similar for spring-calving cows bred on native range during June and July or summer-calving cows bred on either native range or subirrigated meadow during September and October (Table 4).

Summer calving offers advantages for Sandhills cow-calf producers. Perhaps the most significant advantage is

Table 4. Effect of grazing native range or subirrigated meadow during the breeding season on calf weight gains and pregnancy rate (three years).

	Subirrigated meadow	Native range	P-Value
Calf Weight Gain (lbs)	143.6[a]	127.6[b]	.03
Pregnancy Rate[c] (%)	91.6	94.9	.25

[a,b]Means in same row with different superscripts differ (P = .03).
[c]Spring calving cow pregnancy rate = 94.6%.

the reduced amount of hay and labor for feeding hay necessary to winter the cow herd. Summer-born calves weaned at the same age as the spring-born calves were 35 lb lighter at weaning. Savings in feed costs, however, may offset the loss in weaning weight. In addition, January calf prices for the relevant weight of calves tend to be higher than October prices. For the producer selling weaned calves, January calf prices would need to be only about 8% higher than October prices for the summer-born calves to generate equal gross income. In Nebraska, producers received an average of 7.8 percent more for the relevant weight calves in January than in October over the 10-year period 1986-1995. Given the historical price differentials, summer- and spring-born calves will generate similar gross income; therefore, cost savings due to reduced feeding of hay made the summer-born system more profitable at weaning time.

[1]Greg Lardy, former graduate student; Terry Klopfenstein, Professor, Animal Science, Lincoln; Don Adams, Professor; Dick Clark, Professor; Jackie Johnson, research technician, West Central Research and Extension Center, North Platte; Andy Applegarth, ranch manager, Gudmundsen Sandhills Laboratory, Whitman.

Performance of Summer- and Spring-Born Calves Finished as Calves or Yearlings

Greg Lardy
Don Adams
Richard Clark
Terry Klopfenstein[1]

Performance of summer- and spring-born calf-feds and yearling finishing systems will be affected more by seasonality of prices than slaughter breakevens.

Summary

Performance of spring-born calf-fed, early weaned summer-born calf-fed, late-weaned summer-born calf-fed, early weaned summer-born yearlings, and late-weaned summer-born yearlings was evaluated in the two-year study. Neither feeding nor carcass characteristics were influenced by weaning date. No weaning date by calf management system interactions were detected. Spring-born calf-feds had higher initial weights but similar final weights, compared to summer-born calf-feds, and carcass characteristics of spring- and summer-calf-feds were similar. Yearlings had higher initial, final and hot carcass weights, higher dry matter intakes and poorer feed efficiencies compared to summer-born calf-feds. Slaughter breakevens were similar among treatments.

Introduction

Calving date significantly impacts all aspects of cow-calf production, and is not limited simply to issues of matching forage resources to the cows' nutrient requirements. To take advantage of the benefits of changing calving dates, producers may need to change marketing and calf management plans at weaning and post-weaning.

The objectives of this research were to: 1) determine the effect of weaning date on feedlot and carcass characteristics of summer-born steers; 2) determine the effect of calf fed versus yearling feeding system on feedlot and carcass characteristics of summer-born steers; and 3) determine the effect of spring (March to April) versus summer (June to July) calving date on feedlot and carcass characteristics of beef steers.

Procedure

Steers were produced at the University of Nebraska's Gudmundsen Sandhills Laboratory (GSL) and were of MARC II breeding (1/4 Hereford, 1/4 Angus, 1/4 Gelbvieh and 1/4 Simmental composite). Spring-born steers were born beginning March 18, weaned about October 10 and shipped to the University of Nebraska-Lincoln's feedlot at Mead on November 15 in 1994 and 1995.

(Continued on next page)

Table 1. Composition of diet fed to spring and summer-born steers (% DM basis).

Ingredient	%
Dry Rolled Corn	50.0
Wet Corn Gluten Feed	35.0
Corn Silage	5.0
Alfalfa Hay	5.0
Supplement	5.0

Summer-born steers were born beginning June 18. Steers were weaned November 1 (early weaning) or January 10 (late weaning). All steers were backgrounded at GSL until February 14 when steers designated for calf-fed treatments were shipped to Mead for feeding. Steers designated for yearling treatments remained at GSL through the winter, grazed native Sandhills range throughout the summer and were shipped to the Mead feedlot on September 10. Early and late-weaned yearling steers grazed in a common pasture during the summer. Each calving date-feeding system group was fed in two pens each year at Mead.

All steers were fed a common finishing diet (Table 1) based on a blend of dry rolled corn and wet corn gluten feed. Diets were formulated to contain a minimum of 13% CP, .7% Ca, .35% P and .7% K. All diets contained 25 g/ton Rumensin® and 10 g/ton Tylan®. Steers fed as calf-feds were implanted twice during the finishing period with Revalor®; yearlings were implanted once with Revalor® during the finishing period. Breakeven prices for finished cattle were estimated by using 1986-1995 average prices for western Nebraska feeder cattle.

Results

No interactions between weaning date and steer feeding system were detected. Initial and final weights were higher for summer-born yearlings as compared to summer-born calf-feds (Table 2). In addition, initial weights of the spring-born calf-feds were higher than summer-born calf-feds. However, the summer-born calf-feds compensated over the feeding period and had similar final weights compared to spring-born calf-feds. Average daily gains were similar for calving date, weaning date and steer feeding system.

Table 2. Initial weights, final live weights, hot carcass weights, average daily gains, dry matter intakes and feed efficiencies of spring-born steers and summer-born steers as influenced by weaning date and management strategy.

		Summer-born steers				
		Calf-Fed		Yearling		
	Spring-born calf-fed	Early	Late	Early	Late	Contrast[a]
Initial weight	540	444	466	780	776	1, 2
Final weight	1179	1146	1161	1283	1293	2
ADG	3.8	3.9	3.9	4.1	4.2	NS
DMI	20.8	20.6	21.3	26.1	26.8	2
Feed/Gain	5.5	5.3	5.6	6.4	6.4	2
Days on feed	171	181	181	124	124	2

[a]Contrasts: 1, spring vs. summer calf-feds; 2, Summer-born calf-feds vs. summer-born yearlings.

Table 3. Carcass characteristics of spring-born steers and summer-born steers as influenced by weaning date and management strategy.

		Summer-born steers				
		Calf-Fed		Yearling		
	Spring-born calf-fed	Early	Late	Early	Late	Contrast[a]
Hot carcass weight	731	710	720	796	801.7	2
Yield grade	2.0	1.9	1.9	2.0	2.24	NS
Rib eye area	13.5	14.1	13.7	14.2	14.3	NS
Quality grade[b]	18.0	17.9	17.8	18.8	18.2	2

[a]Contrasts: 1, spring vs. summer calf-feds; 2, Summer-born calf-feds vs. summer-born yearlings.
[b]Quality Grade: 17 = Select+; 18 = Choice-; 19 = Choice ; 20 = Choice+.

Dry matter intakes were higher for summer-born yearlings as compared to calf-feds (Table 2). Feed-to-gain conversions were poorer for the yearlings than the calf-feds, but not unexpected. No effect of weaning date was noted for any of the variables measured in the feedlot. Steers from each weaning date were slaughtered at the same time, consequently no differences were noted in days on feed for early and late-weaned summer-born calves or yearlings. Spring-born and summer-born calf-feds were fed for a similar amount of time, while yearlings had significantly fewer days on feed.

Although yearlings had higher hot carcass weights and higher quality grades compared to calf-feds (Table 3), no other differences were noted in carcass characteristics.

Slaughter breakeven was not different for any birth date, weaning date or management system treatment (Table 4). Since marketing dates for slaughter cattle will be different with the various systems, relative profitability of the systems will be affected by sale price. Typically, seasonal prices for slaughter steers are highest in April and lowest in August. In this trial, spring-born steers were marketed in early May, summer-born calf-feds in August and summer-born yearlings in January. The profitability of the summer-born calf-fed system will likely be reduced due to seasonality in prices, not because of slaughter breakevens. However, for the producer who retains ownership, total cost in summer-borns will be lower due to lower costs of producing a weaned calf.

Weaning date influenced neither feeding nor carcass characteristics of summer-born steers. Managing calves for slaughter as yearlings resulted in higher initial, final and hot carcass weights, dry matter intakes and quality grades but poorer feed efficiency compared to calf-feds. No differences were

Table 4. Feed inputs and slaughter breakevens as influenced by birth date, weaning date and management system.

		Summer-born steers			
		Calf-Fed		Yearling	
	Spring-born calf-fed	Early	Late	Early	Late
Value of calf at weaning[a], $	397.43	360.31	396.89	360.31	396.89
Feed Inputs prior to feedlot entry[b], $	21.15	45.37	21.15	118.03	75.74
Summer grazing[c], $	—	—	—	42.00	42.00
Feedlot					
Feed[d], $	174.90	185.85	192.14	160.55	164.64
Yardage[e], $	52.22	54.08	54.08	37.38	37.38
Health[f], $	15.00	15.00	15.00	15.00	15.00
Interest[g], $	23.66	28.56	24.75	52.61	45.18
Total costs, $	684.37	689.20	704.02	785.88	776.84
Slaughter Breakeven, $/cwt[h]	58.67	60.48	61.01	61.92	60.50

[a]Weaning weight * price; Prices=$84.38 for Spring-born, $97.38 for Early Weaned Summer-Born and $91.03 for Late-Weaned Summer-Born.
[b]$45/Ton for Meadow Hay and $170/Ton for Supplement.
[c]Grazing Cost=$0.35/hd/day.
[d]Feed Cost=$0.05/lb.
[e]Yardage=$0.30/hd/day.
[f]Includes parasite control, implants, etc.
[g]Interest=8%/year.
[h]No significant (P<.05) differences.

noted in average daily gain or yield grade. Only initial weights were different when spring and summer calf-fed finishing systems were compared. Slaughter breakevens were similar for all treatments.

Since neither date of birth nor weaning impacted feeding and carcass characteristics or slaughter breakevens of calf-feds, producers who retain ownership can base decisions regarding calving date around marketing plans, seasonal price patterns and the impact of changing calving date on cow productivity.

[1]Greg Lardy, former research assistant, Animal Science, Lincoln; Don Adams, Professor, Animal Science, West Central Research and Extension Center, North Platte; Richard Clark, Professor, Agricultural Economics, West Central Research and Extension Center, North Platte; Terry Klopfenstein, Professor, Animal Science, Lincoln.

Use of the NRC Model for Evaluating Nutrient Balances of Grazing Beef Cattle

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The National Research Council Model is a useful tool for predicting nutrient balances of grazing animals when accurate estimates of digestibility, intake and protein degradability are available.

Summary

Research conducted at the Gudmundsen Sandhills Laboratory evaluated the National Research Council Beef Cattle Nutrient Requirements Model. Equations describing seasonal variability in CP, IVOMD, escape protein and degradable intake protein of native Sandhills range and subirrigated meadow were developed. Estimates of TDN and protein degradability for feedstuffs commonly used by Nebraska cow-calf producers are given. The NRC Model generally predicted nutrient balances in agreement with research trials. Microbial efficiency is lower for less-digestible forages. The NRC model is useful for evaluating grazed diets when accurate estimates of protein degradability, digestibility and intake are available.

Introduction

Recently, the National Research Council revised its Nutrient Requirements of Beef Cattle. One of the most significant changes is the move from expressing protein requirements on a crude protein (CP) basis to a system which uses degraded intake protein (DIP) and metabolizable protein (MP). Protein degraded in the rumen and available for use by the rumen microbes is referred to as DIP, while MP is the protein utilized by the host animal and is the sum of the digestible bacterial protein produced in the rumen and the digestible undegradable intake protein (UIP) from the feedstuffs consumed by the animal. The CP system assumed, inaccurately, a constant degradability for all feedstuffs.

The requirement for DIP is estimated by multiplying TDN intake by microbial efficiency. Microbial efficiency, measure of the amount of TDN which the ruminal bacteria convert to microbial protein, is important. In the NRC model, microbial efficiency determines the amount of DIP required by the ruminal bacteria, as well as the amount of MP supplied to the animal from bacterial fermentation in the rumen.

In order for the NRC model to accurately predict nutrient supply to the

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animal, accurate estimates of digestibility, intake and protein degradability are necessary. For grazing animals, estimates of protein degradability of the diet are lacking.

Our objectives were to: 1) report protein degradabilities for forages and other feedstuffs commonly used in Nebraska; 2) demonstrate the importance of microbial efficiency in determining DIP and MP supplies; 3) use research trials previously conducted at University of Nebraska's Gudmundsen Sandhills Laboratory research facilities to evaluate the NRC model; and 4) present guidelines for successful use of the NRC Model.

Procedure

Research trials previously conducted at the University of Nebraska's Gudmundsen Sandhills Laboratory were used as validation data sets. Refer to previous Nebraska Beef Reports cited in the discussion of each respective validation for complete information on supplements, cattle management and other items related to each trial. For purposes of calculating NE_m balances, in vitro organic matter digestibility (IVOMD) values for supplements and forages were assumed to be equal to TDN.

The PROC REG procedures of SAS were used to develop multiple regression equations for prediction of CP, DIP, escape protein (EP; equivalent to UIP) and IVOMD for native upland range and subirrigated meadow. Because a hierarchical model building process was used, all lower-order terms were included when a higher-order term was included in the model (e.g. if X^3 was significant, X and X^2 were included as well).

Results

Table 1 shows the means and standard deviations in nutritive value for Sandhills range and meadow diets collected with esophageally cannulated cows. The values shown are means of diets collected on native winter range, summer native range and subirrigated meadow regrowth during 1992 and 1994 at the Gudmundsen Sandhills Laboratory (1997 Nebraska Beef Report pp. 3-5). Meadow regrowth was most variable in CP, IVOMD and NDF. This may be expected, since these diets covered August through December, representing high-quality regrowth immediately following haying to dormant forage in early winter. Degraded intake protein, when expressed as a percentage of crude protein, was similar for the three forage types and averaged 84.6%.

Table 1. Means ± standard deviations of crude protein, protein degradability, digestibility, neutral detergent fiber and acid detergent fiber of Nebraska Sandhills forages.

Forage	CP (% of OM)	DIP (% of CP)	IVOMD	NDF (% of OM)	ADF (% of OM)
Summer native range	12.5±2.39	82.3±2.49	66.4±3.37	77.0±4.81	43.6±4.45
Winter native range	6.2±0.45	84.7±2.44	54.0±2.44	84.2±1.61	54.0±1.19
Subirrigated meadow regrowth	13.2±3.89	86.9±2.65	61.7±7.12	71.9±8.80	46.2±6.46

Table 2. Regression equations to predict crude protein, escape protein, degradable intake protein and in vitro organic matter disappearance of subirrigated meadow and native range samples.

Nutrient[a]	Subirrigated meadow Equation[b]	R^2
CP (% of OM)	$1.523698 + 1.346704Z - 0.024693Z^2 + (1.77324 \times 10^{-4})Z^3 - (5.54 \times 10^{-7})Z^4 - (6.27927 \times 10^{-10})Z^5$	.651
UIP (% of OM)	$-4.98141 + 0.543179Z - 0.011468Z^2 + (1.08125 \times 10^{-4})Z^3 - (5.11525 \times 10^{-7})Z^4 + (1.18228 \times 10^{-9})Z^5 - (1.06095 \times 10^{-12})Z^6$	.835
DIP (% of OM)	$2.97353 + 1.120967Z - 0.021132Z^2 + 0.00015405Z^3 - (4.860933 \times 10^{-6})Z^4 + (5.536177 \times 10^{-10})Z^5$	.633
IVOMD	$65.14141 + 0.53003Z - 0.0003067465Z^2$	.477
	Native upland range	
Nutrient[a]	Equation[b]	R^2
CP (% of OM)	$11.119 + 0.062249Z - 0.0006297Z^2 + (1.1781796 \times 10^{-6})Z^3$	.660
UIP (% of OM)	$0.292825 + 0.076754Z - 0.000852403Z^2 + (3.191545 \times 10^{-6})Z^3 - (3.90416 \times 10^{-9})Z^4$	.823
DIP (% of OM)	$9.99572 + 0.035668Z - 0.0004266766Z^2 + (8.168981 \times 10^{-7})Z^3$	.630
IVOMD	$59.54957 + 0.466131Z - 0.005775681Z^2 + (2.192993 \times 10^{-5})Z^3 - (2.665154 \times 10^{-8})Z^4$	.686

[a]CP, crude protein; UIP, undegraded intake protein; DIP, degraded intake protein; IVOMD, in vitro organic matter disappearance.
[b]Z=Day after April 1.

Regression equations for relating date with CP, EP, DIP and IVOMD of native range and subirrigated meadow forages are shown in Table 2. All equations explained at least 50% of the variation in nutrient content's seasonal changes. The highest R^2 values were obtained for EP for both native range and subirrigated meadow. These equations allow forage quality variables to be predicted for any day of the year.

Table 3 shows the effect of changes in microbial efficiency on DIP and MP supplies, requirements and balances for

Table 3. Effect of microbial efficiency on degradable and metabolizable protein requirement, supply and balance for a gestating spring calving cow consuming dormant winter range.

	Microbial efficiency					
	8%	9%	10%	11%	12%	13%
DIP supply (g/d)	436	436	436	436	436	436
DIP requirement (g/d)	494	556	618	680	741	803
DIP balance (g/d)	-58	-120	-182	-244	-305	-367
MP supply (g/d)[a]	393	432	472	511	551	590
MP requirement (g/d)	459	459	459	459	459	459
MP balance (g/d)	-66	-26	13	52	92	131

[a]Microbial MP is calculated in the NRC model from TDN and is not reduced when DIP is less than the requirement.

Table 4. Effect of supplemental rumen degradable protein on DIP and MP supplies, requirements and balances for gestating spring calving cows grazing native winter range.

	Year 1 Treatment[a]			
Item	50%	75%	100%	125%
Daily gain, lb	.13	.09	.20	.14
Condition score change	-.6	-.9	-.8	-.8
NE_m supply	15.7	16.9	15.6	16.3
NE_m requirement	16.4	16.4	16.4	16.4
NE_m balance	-0.7	0.5	-0.8	-0.1
DIP supply	642	760	797	892
DIP requirement	663	716	657	689
DIP balance	-21	44	140	203
MP supply	521	557	505	525
MP requirement	455	455	455	455
MP balance	66	102	50	70

	Year 2 Treatment[a]			
Item	29%	65%	100%	139%
Daily gain, lb	.10	.39	.14	.02
Condition score change	-.2	0	-.4	-.3
NE_m supply	13.8	13.9	13.9	13.8
NE_m requirement	16.6	16.6	16.6	16.6
NE_m balance	-2.8	-2.7	-2.8	-2.8
DIP supply	491	567	648	709
DIP requirement	586	589	589	586
DIP balance	-95	-22	59	123
MP supply	463	460	455	448
MP requirement	459	459	459	459
MP balance	4	1	-4	-11

[a]Treatments based on percentage of estimated supplemental degradable intake protein requirement (1996 Nebraska Beef Report, pp. 14-16).

a gestating spring-calving cow consuming dormant winter range. As microbial efficiency changes from 8 to 13%, DIP goes from slightly deficient to highly deficient, while MP moves from deficient to adequate (model does not reduce MP if DIP is deficient). In general, less-digestible forages, which pass from the rumen at slower rates, have lower microbial efficiencies. Forages which pass slower result in slower microbial growth, lowering both the requirement for DIP and the amount of MP produced by the bacteria which ferment that forage. Forages which have higher digestibilities result in more microbial growth which increases the requirement for DIP.

For cows grazing winter range and other low quality forages, we suggest using microbial efficiencies of 9 - 10%. Data collected at the Gudmundsen Sandhills Laboratory with gestating cows grazing winter range support the use of 9-10% microbial efficiency for most dormant forages (1993 Nebraska Beef Report, pp. 8-10; 1994 Nebraska Beef Report, pp. 5-7; 1996 Nebraska Beef Report, pp. 14-16; 1997 Nebraska Beef Report, pp. 8-10). With vegetative forages and high-quality hays, we suggest using 13% efficiency. Using a too-high microbial efficiency will result in over-prediction of the DIP requirement and overestimation of the supply of MP.

Ruminants have the ability to recycle nitrogen to the rumen in the form of urea. Therefore, excess MP (or UIP) can likely substitute for DIP. However, excess DIP cannot substitute for MP or UIP. Because of this ability to recycle nitrogen, slight deficiencies in DIP may not be detrimental to performance, especially when MP supply is greater than the requirement.

Table 4 shows the effect of supplemental rumen degradable protein for gestating spring-calving cows grazing native winter range on NE_m, DIP and MP supplies, requirements and balances (1996 Nebraska Beef Report, pp. 14-16). In Year 1, cow weight and condition score changes were similar for all treatments. In Year 2, cows responded in a quadratic manner to level of supplemental DIP. Based on the cow weight change and condition score data, the rumen degradable protein requirement was not met by the 29% level in Year 2. The NRC model predicted DIP was slightly deficient at the lowest level of supplementation and was adequate for all other treatments in Year 1, indicating only small amounts of supplemental rumen degradable protein are

(Continued on next page)

required to meet the DIP requirement. In Year 2, the NRC model predicted that cows fed at 29% of the estimated supplemental rumen degradable protein requirement were deficient in DIP. In Table 4, the NRC model calculations were completed using a microbial efficiency of 9%. Model predictions were accurate when this efficiency value was used.

Table 5 shows the effect of supplemental ear corn and/or protein for gestating spring-calving cows grazing native range on cow performance, NE_m, DIP and MP supplies, requirements and balances. The NRC model predicted DIP levels were adequate for the protein treatment and deficient for the supplemental ear corn and ear corn plus protein treatments. A 9% microbial efficiency was used to calculate the DIP requirements and MP supplies in Table 5. Cow weight gains were highest for the protein supplemented treatments, intermediate for the ear corn plus protein and lowest for the ear corn treatment. Net energy for maintenance balances were negative for all treatments. It is possible the treatments containing supplemental ear corn reduced digestibility and intake of the range forage; however, no effort was made to model these possibilities as they were not measured in the trial. If intake and digestibility were reduced when supplemental ear corn was fed, NE_m balances would be more negative for the treatments containing supplemental ear corn. The NRC model does not reduce energy digestibility when DIP is deficient. This trial illustrates the importance of meeting the DIP requirement, especially when energy is supplemented.

Table 6 gives suggested values for effective NDF, CP, DIP and TDN for feedstuffs commonly used by cow-calf operations in Nebraska. When actual analysis values for a particular feedstuff are available, the values from the analysis should be used. These suggested figures serve only as guidelines.

Table 7 gives guidelines for successful use of the NRC Model with grazing cattle. As with any computer program, the output is highly dependent on the input. Critical areas in the input section which need attention are: 1) Microbial yield (efficiency); 2) the 'On Pasture' feature; and 3) the Environment section. Microbial yield impacts both DIP requirement and MP supply. We suggest using 9 - 10% for low-quality hays, winter range and similar forages. Add 1% for lactating cows. Use 13% for vegetative forages, high-quality hays and other forages > 60% TDN. For straws, corn stover and other forages < 50% TDN use 8%. The 'On Pasture' feature will automatically raise energy requirements by approximately 25% as

Table 5. Effect of supplemental ear corn, ear corn plus protein or protein on cow performance, NE_m, DIP and MP supplies, requirements and balances for gestating spring calving cows grazing native winter range.

	Treatment[a]		
Item	Ear corn	Ear corn + protein	Protein
Cow weight change, lb	-121.0[b]	-40.3[c]	14.6[d]
NE_m supply	15.2	15.3	14.6
NE_m requirement	16.4	16.4	16.5
NE_m balance	-1.2	-1.1	-1.9
DIP supply	459	569	628
DIP requirement	632	634	613
DIP balance	-173	-65	15
MP supply	543	577	537
MP requirement	458	458	458
MP balance	85	119	79

[a]Treatments were 3.5 lbs supplemental ear corn; 3 lbs supplemental ear corn plus 1 lb 40% protein cube; or 2 lbs 32% protein cube (1987 Nebraska Beef Report, pp. 36-37).
[a,b,c,d]Means in the same row with different superscripts differ, (P<.05).

Table 6. Suggested values for feedstuffs commonly used by Nebraska cattle producers.

	eNDF	TDN	CP	DIP
Protein meals				
Soybean meal	0	88	49.9	70
Sunflower meal	0	65	25.9	81
Cottonseed meal	0	75	46.1	57
Feather meal	0	88	85.8	30
Blood meal	0	88	90.5	25
Distillers solubles/steep liquor (dry milling)	0	88	28	80
Distillers solubles/steep liquor (wet milling)	0	88	36	80
Harvested forages				
Corn silage	71	75	7.4	75
Alfalfa hay	100	60	16	82
Brome hay, mid bloom	100	66	14.4	84
Alfalfa hay, early vegetative	100	74	30	93
Alfalfa hay, late vegetative	100	67	20.3	85
Meadow hay, high quality	100	67	16.2	87
Prairie hay[a]	100	49	6.8	80
Prairie hay[a]	100	53	7.7	75
Grazed forages				
Sandhills range, June diet	100	68	12.4	82
Sandhills range, July diet	100	67	10.9	82
Sandhills range, August diet	100	64	10.0	84
Sandhills range, September diet	100	59	6.6	86
Winter native range	100	54	6.2	85

[a]Match to nearest CP value.

Table 7. Suggested inputs and guidelines for use of the 1996 NRC model.

1. **Units and Levels Section.**
   Use only Level 1, unless rates of digestion of all feed fractions are known.

2. **Animal Section.**
   Remember that your choice of breed affects maintenance energy requirements.
   Bos indicus cattle have lower NE_m requirements, while dairy and dual purpose breeds have higher requirements. This is discussed in detail in the textbook accompanying the NRC Model.

3. **Management Section.**
   A. Using the '**On Pasture**' feature in the management section will increase maintenance energy requirements by approximately 25% with level terrain and 50% with hilly terrain. The value can be input as a range between 1 (level) and 2 (hilly) in 0.1 unit increments. We recommend using this feature cautiously. In many cases, maintenance energy requirement is not increased by 25% while cattle are on pasture. Requirements are calculated accurately for pasture cattle even if this 'On Pasture' feature is turned off.
   B. **Microbial Yield.** Use 13% (default) for all vegetative forages and forages above 60% digestibility. For lower quality forages such as winter range or hays below 55% TDN use a microbial efficiency of 9-10%. Values as low as 8% may be necessary when the diet consists of mainly straw, stover, or other forages below 50% TDN which have lower passage rates. After calving, intakes and passage rates increase, therefore, microbial efficiency should be increased one percentage unit above that of a gestating cow fed the same forage.

4. **Environment Section.**
   A. **Temperature.** Because of daily fluctuations in temperature, it is difficult to state a temperature which the cattle are subjected to. Interactions also exist with other environmental factors which are discussed below. We recommend using long term average temperatures for a given month or season at a given location.
   B. **Wind speed.** Caution is needed when using this feature. Because cattle behavior is impacted by wind speed, cattle are not subjected to reported wind speeds. Wind speed is generally measured by anemometers positioned 10' above ground. Cattle are seldom subjected to these wind speeds because they will find ways to minimize the effect of wind on them. We recommend using wind speeds of less than 5 miles per hour in most cases.
   C. **Hair Depth.** Use .25 inches in the summer and .5 inches for winter coats.
   D. **Hide.** Use 1 (thin hide) for Bos indicus and dairy breed types, and 2 (average) or 3 (thick) for most English and Continental breeds.

5. **Feeds Section.**
   A. Use the **Feed Library** (a feature separate from the model) to make global changes to feedstuff composition. Use the **Feed Composition** feature to make feed composition changes specific to a ration or problem (composition changes made in this manner will be specific to that input file only).
   B. When estimates of feed intake are unavailable or unknown, use the NRC estimated intake as a guideline. Use the following as **general** guidelines. Dry gestating cows will generally consume 1.8-2.0% of body weight, while lactating cows will consume 2.3-2.5% of body weight.

a way of accounting for the energy cost of grazing activity. In some cases, when hilly terrain is an entered factor, the increase in energy requirement predicted by the model will be as high as 50%. We recommend cautious use of this feature. Grazing activity does require the animal to expend energy; however the increases predicted by the model may sometimes be unrealistic. The model also is very sensitive to environmental inputs, particularly wind speed, when the animal is below its lower critical temperature. We recommend wind speeds of less than 5 mph.

The NRC model is a useful tool for evaluating grazed diets when accurate estimates of protein degradability, digestibility and intake are available. Microbial efficiency appears to be lower for less-digestible forages which have slower rates of passage. The finding that only small amounts of DIP are necessary to maintain gestating beef cows indicates that microbial efficiency is relatively low on these low quality forages. Microbial efficiency has a large impact on estimates of DIP requirement and consequently MP supply.

Dried Poultry Waste as a Protein Supplement for Cows Grazing Winter Forages

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Replacing soybean meal with dried poultry waste and feather meal was effective when supplementing cows grazing either native Sandhills winter range or cornstalks and saved $55/ton in supplement ingredient costs.

Summary

Two trials conducted in 1996-1997 evaluated dried poultry waste relative to soybean meal for cows grazing winter forages. In Trial 1, cows grazing native Sandhills winter range received: 1) no supplement; 2) urea; 3) 22% dried poultry waste+urea; 4) soybean meal; 5) 22% dried poultry waste+soybean meal; or 6) 44% dried poultry waste. Cows receiving supplements gained more weight (P<.001) and maintained greater body condition (P<.001) than unsupplemented cows. Cows receiving urea gained less (P<.10) than cows receiving more natural protein, although body condition remained similar. In Trial 2, cows grazing cornstalks received supplements containing either soybean meal or dried poultry waste; however, gains were not different.

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Introduction

Cornstalks and winter range typically are utilized by cow/calf producers in the Midwest and Central Great Plains as economical alternatives to higher-priced harvested forages. However, grazed winter forages are often deficient in degradable intake protein (DIP) and do not meet the metabolizable protein needs of the gestating cow. Degradable intake protein provides nitrogen to the microbial population and aids in forage digestion. Generally, supplemental protein is fed to meet these needs. As a result, protein supplementation is often the most costly aspect of production and an area which can be improved. One way to lower supplement cost is to find alternative, less-expensive protein sources which adequately meet the cows DIP requirement. Dried poultry waste (DPW) is an acceptable source of DIP for calves on a growing ration; however, DPW has not been evaluated as a source of DIP for cows grazing low-quality forages. Dried poultry waste is approximately 28% protein and 35% ash. Of the 28% protein, 49% is true protein; the remainder is uric acid. In addition, DPW brings minerals such as calcium, phosphorus, copper and zinc to the supplement, further reducing supplement costs.

Two trials were conducted to evaluate dried poultry waste relative to soybean meal (SBM) as a degradable intake protein source for cows on low-quality forages.

Procedure

Trial 1

To evaluate DPW as a DIP source, 60 cows (5 yr, 1,223 lb) grazing native Sandhills winter range were used in a 108-d individual supplementation trial beginning November 19, 1996 and ending March 4, 1997. Cows were assigned randomly to one of six supplemental treatments (10 hd/treatment). Treatments (Table 1) consisted of: 1) No supplementation; 2) Urea; 3) 22% DPW + Urea; 4) SBM; 5) 22% DPW + SBM; and 6) 44% DPW. In addition, feather meal was added in varying amounts to each supplement in order to supply adequate undegradable intake protein (UIP) to the cows and to equalize UIP content. Supplements were formulated to be equal in terms of both DIP and UIP and fed in a cube form (7/8"). Cows were offered 2 lb (as-is) on Monday and Wednesday and 3 lb on Friday. Cows were gathered from a common pasture, sorted in a temporary corral, placed into an individual pen and fed the assigned supplement. Cows were given several minutes to consume their supplement; however, most were finished within 5 minutes. Cows on the control treatment were sorted in the corral and turned back into the pasture. All cows were allowed *ad-libitum* access to salt and limestone.

Forage intake was determined from the fecal output and forage indigestibility of 36 cows (6 cows/treatment) over a five-day collection period (December 16, 1996 through December 20, 1996). Five days prior to the start of collection, cows on the intake portion of the trial were dosed with an intraruminal continuous chromium-releasing bolus to determine fecal output.

Five, 550 lb steers were fitted with fecal collection bags for a total fecal collection and dosed with the same intraruminal continuous chromium-releasing boluses as the cows to determine a correction factor for chromium payout.

Diet samples were collected from six esophageally-fistulated cows (1,250 lb) on one day during the intake period. Although a second diet collection was planned, inclement weather would not permit it. Diet samples were freeze dried, ground and analyzed to determine CP, UIP and digestibility. Forage intake was determined by dividing fecal output by indigestibility of the range diet collected by the esophageally fistulated cows.

Initial and final weights were determined by taking the average of two consecutive day weights at the beginning and end of the trial. A one day midpoint weight also was collected. Body condition scores (1 = thinnest to 9 = fattest) also were determined by palpation of the ribs and thoracic vertebrae at the beginning, middle and end of the trial.

Trial 2

A completely randomized design using 48 cows (6 yr, 1,300 lb) evaluated a supplement containing DPW versus a supplement containing SBM for cows grazing winter corn residue from November 5, 1996 through January 8, 1997. Treatments were: 1) SBM; and 2) 44%

Table 1. Supplement composition for Trials 1 and 2.

	Supplement (% of DM)[a]				
Ingredient	Urea[b]	22% DPW + Urea[b]	SBM[b,c]	22% DPW + SBM[b]	DPW[b,c]
Wheat midds	27.1	18.4	8.26	9.19	8.22
Soybean hulls	27.1	18.4	8.26	9.19	8.22
Feather meal	23.6	24.8	11.5	18.8	26.3
Dried poultry waste	——	22.0	——	22.0	44.0
Urea	3.44	1.7	——	——	——
Soybean meal—47%	——	——	54.5	26.9	——
Molasses	4.0	4.0	4.0	4.0	4.0
Tallow	2.0	2.0	2.0	2.0	2.0
Salt	2.64	2.30	2.88	2.41	1.94
Dicalcium phosphate	2.5	0.42	2.06	0.21	——
Potassium chloride	1.3	0.61	——	——	——
Copper sulfate	0.08	0.056	0.036	0.034	0.033
Limestone	1.0	——	1.16	——	——
Zinc sulfate	——	——	0.044	0.021	——
Vitamin A, D, E	0.25	0.25	0.25	0.25	0.25
Ameribond	5.0	5.0	5.0	5.0	5.0

[a]DPW=dried poultry waste; SBM = soybean meal.
[b]Trial 1 supplements.
[c]Trial 2 supplements.

Table 2. Weight gains of cows grazing native Sandhills winter range (Trial 1).

	Treatment[a]						Contrasts[b] (P =)				
Item[a]	Control	Urea	DPW + Urea	SBM	DPW + SBM	DPW	A	B	C	D	E
IWT, lb	1226	1219	1225	1204	1223	1219	NS	NS	NS	NS	NS
MWT, lb	1179	1195	1197	1181	1187	1192	NS	NS	NS	NS	NS
FWT, lb	1169	1217	1247	1216	1243	1242	0.08	NS	NS	NS	NS
ADG, lb/d											
days 0-53	-0.89	-0.44	-0.53	-0.43	-0.68	-0.51	0.07	NS	NS	NS	NS
days 53-106	-0.19	0.41	0.95	0.65	1.05	0.95	<0.001	0.006	0.09	NS	NS
days 0-106	-0.54	-0.02	0.21	0.11	0.18	0.22	<0.001	0.10	NS	NS	NS

[a]DPW = dried poultry waste; SBM = soybean meal; IWT = initial weight; MWT = mid-point weight; FWT = final weight.
[b]Contrasts were A (control vs. urea, DPW + urea, SBM, DPW + SBM, DPW), B (urea vs. DPW + urea, SBM, DPW + SBM, DPW), C (SBM vs. DPW + Urea, DPW + SBM, DPW), D (DPW vs. DPW + urea, DPW + SBM), E (DPW + urea vs. DPW + SBM); NS = nonsignificant.

DPW. Supplements were the same as treatments 4 (SBM) and 5 (44% DPW) in Trial 1 (Table 1). Cows were assigned randomly to one of six irrigated corn fields (3 cornfields/treatment) at a stocking rate of 0.8 hd/acre. Supplements were fed once daily at 1.25 lb (as-is) in a cube form (7/8").

Animal performance was measured in terms of ADG. Both initial and final weights were the average of two consecutive day weights following three days of limit feeding at 2% of body weight. Cows were removed from fields when, based on visual appraisal, quantity of forage became limiting.

Results

Trial 1

Cows consuming supplement gained more weight (Table 2) and maintained more body condition ($P<.001$) than unsupplemented cows. Each treatment entered the trial with BCS ranging from 5.0-5.2. By the end of the trial, supplemented cow BCS averaged 4.3, while unsupplemented cows had an average BCS of 3.9. Average daily gain and BCS results indicate the control cows were deficient in DIP. Other work supports this conclusion and has shown native Sandhills winter range is deficient in supplying cows with DIP and that cows may respond positively to DIP supplementation (1996 Nebraska Beef Cattle Report, pp. 14-16). However, because supplemented cows did receive energy and added minerals from the supplements, at least some of this response may have been due to energy or any one of the supplemented minerals such as Cu, Zn or P.

Overall, cows consuming natural protein supplements performed better ($P<.10$) than cows fed urea, indicating protein may be required either by the animal or the microbial population (Table 2). Natural protein may be important as a source of amino acids to be utilized by the microbial population. Protein also may have a slower rate of nitrogen release which more closely corresponds to energy release from the slowly digested winter forage. By feeding on alternate days, urea, which is highly soluble in the rumen, would have been immediately available to the microbial population. Due to the slow rate of forage digestion, however, energy would be limiting to microbial protein production, making the microorganisms dependent upon nitrogen recycling by the animal as energy became available. Body condition scores of cows supplemented with urea were similar to those of cows supplemented with natural protein.

Compared to SBM, cows consuming supplements containing DPW had similar weight gains (Table 2) and BCS throughout the trial. No differences were found in ADG (Table 2) or BCS throughout the trial for cows consuming 44% DPW, 22% DPW + urea or 22% DPW + SBM.

Cows consuming either 22% DPW + urea or 22% DPW + SBM had similar ADG (Table 2) and equal BCS. Therefore, if natural protein was required by the microbial population, the DPW and feather meal were supplying adequate amounts.

Esophageally fistulated cows were able to consume diets containing 6.84% CP (DM basis), of which 0.55% was UIP (DM basis). *In vitro* organic matter disappearance (IVOMD) of diets collected by esophageal cows was 48.5% (DM basis), slightly below IVOMD values typically seen (50-52%) on native Sandhills winter range. However, diet collections for this trial were taken one day after four consecutive sub-zero days. Cows may have experienced limited grazing time in the days previous to collections, were hungry, and therefore less selective.

No differences were found in forage organic matter intake (lb; Table 3) or total organic matter intake (lb; Table 3) throughout the trial.

Trial 2

No differences in ADG between DPW and SBM were observed. Performance of cows consuming SBM or DPW were -0.61 and -0.62, respectively. The fact that cows lost weight would indicate the corn residue was of a poorer quality than in previous years.

A major factor determining residue quality is the amount of corn grain remaining in the field after harvest. Initially, corn grain supplies a substantial amount of protein and energy to the cows and accounts for a significant portion of gain. Based on samples collected for other cornstalk grazing trials in 1996-97, little residual corn was available in fields.

Protein studies, especially those using cornstalk grazing, can be confounded by corn intake. The fact that cows are consuming *ad-libitum* quantities of corn residue and the variable

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Table 3. Cow daily forage and total organic matter intake (Trial 1).

	Treatment[a]						Contrasts[b] (P =)				
Item[a]	Control	Urea	DPW + Urea	SBM	DPW + SBM	DPW	A	B	C	D	E
FOMI (lb)	29.9	29.6	27.8	29.2	27.3	28.1	NS	NS	NS	NS	NS
TOMI (lb)	29.9	30.4	28.6	30.0	28.1	28.9	NS	NS	NS	NS	NS

[a]DPW = dried poultry waste; SBM = soybean meal; FOMI = forage organic matter intake; TOMI = total organic matter intake.
[b]Contrasts were A (control vs. urea, DPW + urea, SBM, DPW + SBM, DPW), B (urea vs. DPW + urea, SBM, DPW + SBM, DPW), C (SBM vs. DPW + Urea, DPW + SBM, DPW), D (DPW vs. DPW + urea, DPW + SBM), E (DPW + urea vs. DPW + SBM); NS = nonsignificant.

amount of downed corn often do not allow for the control of corn intake by animals in trials such as these.

Another likely factor for the observed weight loss was inclement weather. When energy requirements become greater than can be met by available forage, animals mobilize body reserves for heat production. Although the weather was favorable during most of the trial, a relatively severe cold period did occur during the last two weeks of the trial. This cold period also corresponded to the time of most limited forage.

Based on visual observations throughout both Trials 1 and 2, DPW is as acceptable to cows as SBM. In both trials, with the exception of a single animal on the DPW treatment in each, the cows readily consumed all supplements. Cows in both Trials 1 and 2 came to the supplements and quickly consumed all cubes from day 1 through the end of the trials.

For cows on winter range or cows consuming corn residues, dried poultry waste and feather meal appear to be viable substitutes compared to more traditional protein supplement ingredients such as soybean meal. Economic analysis of the DPW and SBM supplements used in the present trials indicate the DPW supplement was $57 less/ton, resulting in a savings of $0.04/hd/day and a total savings over 80 days of $3.20/hd.

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Escape Protein Supplementation and Weaning Effects on Calves Grazing Meadow Regrowth

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High-quality meadow regrowth is limiting in escape protein. Milk is an important source of metabolizable protein however, milk intake in late lactation may not be sufficient to maximize growth of nursing calves.

Summary

Forty spring-born calves grazing subirrigated meadow regrowth were assigned to two weaning and two supplementation treatments in the fall of 1995 and 1996. Weaning treatments were: 1) weaning September 1; or 2) nursing during the trial. Supplementation treatments were 1) no supplemental undegraded intake protein (escape protein); or 2) supplemental undegraded intake protein. No treatment interactions were detected indicating weaning and supplementation affects were independent. Nursing calves had higher weight gains (2.1 versus 1.3 lb/day) and lower forage intakes (5.2 versus 6.5 lb/day) than weaned calves. Supplemental undegraded intake protein increased weight gains of calves (1.94 versus 1.45 lb/day). We concluded subirrigated meadow forage was limiting in metabolizable protein and milk was an important source of metabolizable protein.

Introduction

For the nursing calf, milk represents an important source of nutrients. Milk bypasses rumen fermentation by the esophageal groove reflex and is digested and absorbed in the abomasum and small intestine. Because of this reflex, milk protein represents an important contribution to the metabolizable protein supply for the nursing calf. Nursing calves have higher relative protein requirements than more mature animals.

Generally, when cattle graze cool-season grasses, ruminal ammonia concentrations do not limit microbial growth and fermentation. However, because of the degradable nature of the protein in these grasses, large amounts of nitrogen can be lost as ammonia before reaching the duodenum. Therefore, it is possible for metabolizable protein to be limiting in forages which have relatively high crude protein contents, especially if relative requirements are high.

Numerous studies have evaluated

the effects of early weaning on cow and calf performance. However, these studies generally involved feeding early weaned calves large amounts of concentrates or grains, rather than leaving calves in a grazing setting. Few studies have evaluated the effect of early weaning on calf performance, where calves graze high-quality forages after weaning. Effects of supplemental, undegraded intake protein on forage intake and performance of the weaned and nursing calves grazing high-quality forage are not well-defined. Supplying undegraded intake protein in the form of milk or in a supplement may increase performance of calves grazing meadow regrowth if metabolizable protein is deficient in those forages. Our objectives were to evaluate the effects of milk intake and supplemental undegraded intake protein on calf performance and forage intake while grazing subirrigated meadow regrowth in the Nebraska Sandhills.

Procedure

The study was conducted at the University of Nebraska-Lincoln Gudmundsen Sandhills Laboratory. Forty spring-born crossbred calves were assigned in each year to two weaning and two supplementation treatments during the fall of 1995 and of 1996. Because the calves did not readily consume supplements until mid-October, 1995, the trial lasted from October 17 to November 18. In 1996, however, the calves readily consumed supplements from the outset and the trial lasted from September 5 to November 4. Each year, calves grazed subirrigated meadow regrowth after July haying. Weaning treatments were: 1) weaning before the trial began (September 1); and 2) nursing throughout the trial. Supplementation treatments were: 1) no supplementation; or 2) supplemental undegraded intake protein. Supplement composition is listed in Table 1. Weaned calves receiving supplement were individually fed 2.0 lb of supplement daily; nursing calves received 1.1 lb supplement daily.

Calves were gathered each day at 7:30 a.m. and individually fed their supplements. In order to prevent nursing by weaned calves, the subirrigated meadow pasture was split in 1995 into two pastures; nursing calves grazed on one side, and weaned calves on the other. Each day, following supplementation, nursing and weaned calves rotated pastures. Over the course of the trial, each group of calves grazed each side a similar number of days. In 1996, nursing and weaned calves were pastured together and observed for cross nursing. No nursing by weaned calves was observed in either year. Milk intake by nursing calves was determined by weigh-suckle-weigh on November 4, 1995 and October 18, 1996.

Table 1. Composition of supplement fed to weaned and nursing calves (dry matter basis).

Ingredient	% of DM
Sulfite liquor treated soybean meal	80.0
Feather meal	20.0
	% of OM
Crude protein	57.3
In vitro organic matter disappearance	79.5
Undegraded intake protein, % crude protein[a]	78.8

[a]Determined using ammonia release procedure.

Fecal output was determined on steer calves during October of each year. Each steer calf was dosed with a chromium-releasing Captec bolus. Fecal output was calculated by dividing the amount of chromium released by the Captec bolus by the chromium concentration in the feces. Forage intake was calculated by dividing fecal output by indigestibility of the subirrigated meadow diet.

Forage diet samples were collected with three esophageally fistulated cows and three ruminally fistulated nursing calves. Extrusa samples were analyzed for DM, OM, CP, NDF, ADF, IVOMD and protein degradability

Results

Year effects were significant for initial weight and average daily gain ($P = 0.06$ and 0.04, respectively). Initial weights averaged 478.3 and 423.9 lb in 1995 and 1996, respectively. These weights were higher in 1995 because of the difficulties in getting calves to consume supplements, which caused the trial to start later than anticipated. Average daily gains averaged 1.52 and 1.87 lb day^{-1} in 1995 and 1996, respectively, and again were likely influenced by the starting date of the trial.

Calves and cows selected diets which were similar in quality. Diets collected with ruminally cannulated calves averaged 12.5% CP and 54.8% IVOMD (Table 2). While grazing meadow regrowth, calves tended to select diets higher in undegraded intake protein than cows (Table 2).

No supplementation by weaning management interactions were detected for initial weight, final weight or average daily gain. No supplementation by weaning management interactions were detected for forage intake, total intake, forage intake as a percentage of body weight or total intake as a percentage of body weight. Therefore only main effects will be presented and discussed.

Nursing calves had higher average daily gains and higher final weights ($P < .01$) compared to weaned calves (Table 3). Due to the magnitude of this response, it is apparent that milk was an important source of nutrients for the growing calf. Nursing calves gained

(Continued on next page)

Table 2. Crude protein (CP), undegraded intake protein (UIP), neutral detergent fiber (NDF), acid detergent fiber (ADF) and in vitro organic matter digestibility (IVOMD) of diet samples collected from cows and calves grazing subirrigated meadow regrowth in 1995 and 1996.

		% of organic matter				
Date	Type	CP	UIP	NDF	ADF	IVOMD
27 Oct., 1995	Cow	10.0	1.94	84.4	57.2	53.1
27 Oct., 1995	Calf	10.9	2.45	83.9	55.9	50.1
3 Nov., 1995	Calf	11.5	2.21	76.3	53.0	56.1
15 Oct., 1996	Cow	11.1	1.78	76.5	53.2	55.7
15 Oct., 1996	Calf	11.2	2.72	88.8	63.0	56.7
16 Oct., 1996	Calf	16.2	3.09	94.4	69.8	56.3

Table 3. Effect of weaning and supplementation on ADG and intake.

	Main effects[a]					
	Weaning management			Supplementation		
	Weaned	Nursing	P-value	Non-supplemented	Supple-mented	P value
Initial weight (lb)	432	470	.2072	457	446	.7560
Final weight (lb)	490	569	.0099	524	535	.6847
ADG (lb/day)	1.3	2.1	.0009	1.5	1.9	.0306
Forage intake (lb/day)	6.5	5.2	.0090	6.0	5.7	.3257
Total intake (forage + supplement, lb/day)	7.50	5.74	.0040	6.00	7.26	.0111
Forage intake (% body weight)	1.29	0.89	.0074	1.17	1.02	.0927
Total intake (forage + supplement, % body weight)	1.48	0.99	.0048	1.17	1.30	.1388

[a]All supplement by weaning management interactions were nonsignificant at P>0.15.

0.79 lb/day more than weaned calves over a 60 day grazing period, resulting in over 44 lb of body weight gain per calf. Lactation effects on weight and body condition score changes in the cow were not investigated. Previous research at Gudmundsen Sandhills Laboratory indicated lactating two-year-old cows will maintain weight and body condition while grazing meadow regrowth (1996 Nebraska Beef Report, pp. 3-5), however body condition increased when cows were dry.

Calves receiving undegraded intake protein supplementation had higher (P = 0.03) weight gains compared to nonsupplemented calves (Table 3). Weaned and nursing calves responded to supplemental undegraded intake protein in a similar fashion, indicating the undegraded intake protein was likely first limiting for both weaned and nursing calves.

Forage intake and total intake, when expressed either as a percentage of body weight or as an amount, were higher (P<.01) for weaned compared to nursing steers (Table 4). Although weaned calves compensated for lack of milk intake by increasing forage intake, this compensation was not enough to increase weight gains to levels of nursing calves, indicating the importance of milk for the growing calf.

No differences were found in forage intake for supplemented or non-supplemented steers. Intake of forage and supplement were higher (P < .01) for supplemented steers. Forage intake, as a percentage of body weight, tended to be higher for nonsupplemented steers (P=.09). Total intake, expressed as a percentage of body weight, tended to be higher for supplemented calves (P=0.14).

Milk consumption averaged 12.8 and 14.5 lb milk/day for supplemented and nonsupplemented calves, respectively. Assuming milk contains 3.4% protein, these milk intakes would supply 0.43 and .46 lb metabolizable protein, respectively. For the nursing calves not receiving the undegraded intake protein supplement, this represents over 50% of the metabolizable protein supply. However, based on the supplementation performance responses, milk may not supply adequate metabolizable protein to meet the requirements for the level of daily gain by the calves that other nutrients in the grazed forage would support.

Commonly accepted practices of creep feeding cereal grains to nursing calves may not correct metabolizable protein deficiencies in high quality forages. Creep feeding small amounts of protein supplements high in undegraded intake protein may increase weight gains in nursing and weaned calves grazing high-quality forages.

We concluded that high-quality forages, such as subirrigated meadow regrowth, may be limiting in metabolizable protein for growing calves. Even though milk represents an important source of metabolizable protein, milk intake in late lactation may not be high enough to support the level of growth that would be supported by the energy consumed.

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Calving Difficulty and Calf Response to Stress

Todd Cappel
Andrea Bueno
Edd Clemens[1]

Calving difficulty of the heifer can significantly depress some of her calf's physiological resources used to adjust to the stress of their new environment.

Summary

Calving difficulty altered the stress-related capabilities of the calf, placing the newborn in a compromised situation. Calves derived by severe mechanical pull or cesarean section exhibited depressed short-term defensive capabilities, lower cortisol and elevated neutrophil values, necessary for fighting infectious organisms. Of equal concern: when compared to calves born with little or no parturition difficulty, the stressed calves failed to develop effective adaptive mechanisms, having lower thyroid activity and lymphocyte values of principle importance for long-term survival. Neither the heifer's mothering ability nor her disposition tended to influence her calf's stress indicators.

Introduction

Parturition can be stressful for both the first calf heifer and her calf. Several physiological changes occur responding to the stress of parturition in an effort to maintain normal body function. For example, fetal cortisol is thought to be one of the primary changes in the calf's blood that initiate parturition in cattle. With respect to thermoregulation, T_3 has pronounced effects on brown adipose tissue utilization and subsequently the thermogenesis of the newborn.

Calf mortality represents a economic loss to the beef industry. Studies suggest the number of calves lost from calving difficulty (50.9%) exceeded losses from all other causes. Calf death due to calving difficulty also accounted for the single largest loss category through the first 96 hours of life. Therefore, calving difficulty, and the endocrine response to stress represents a major part of all economic loss in the cow herd. This study was designed to evaluate the relationship between the severity of calving difficulty and the hormone concentration and blood composition of the heifer and her calf.

Procedure

A total of 104 first-calf heifers were used in the experiment, over a two-year period. The heifers were from four university herds. The first two groups included; 36 MARC-MARC III and 10 purebred Angus first-calf heifers from the Agriculture Research and Development Center (ARD) near Mead, Nebraska. For these, the calving season began February 17 and ended March 12, 1995. During the second-year calving season, February 24 to April 4, 1996, 18 MARC II first-calf heifers from the West Central Research and Extension Center at North Platte, and 40 3/4 Angus X 1/4 Gelbvieh heifers from the ARD Center near Mead, Nebraska were sampled.

Pregnant heifers, kept in a calving pasture with free access to water and alfalfa hay, were checked at one hour intervals for oncoming signs of parturition. After exhibiting stage II labor for one hour (i.e. rupture of the fetal sac, fluid escape from the vulva and abdominal strain) the heifer was brought into the calving barn. An experienced herdsman assisted each heifer at parturition and assessed the level of calving difficulty (Table 1).

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Table 1. ARD calving score assigned to each parturition.

Calving Score	Assignment Criteria
1.	Unassisted delivery.
2.	Little difficulty. Assistance given by hand, but no calfjack or puller used. Assistance may not have been required.
3.	Moderate difficulty. Calfjack was used, typically pull duration was less than 10 minutes.
4.	Major difficulty. Calfjack used and major difficulty encountered. Duration of pull longer than 10 minutes.
5.	A cesarean section was preformed.

Immediately following birth, blood samples were obtained from the heifer and calf via jugular venipuncture. Calves were then bled in the same manner at 24, 48 and 72 hours of age. Dates, calving time and blood sampling were recorded. The dam's disposition and mothering ability were also assessed and the climatic conditions at the time of birth recorded. After ensuring proper postpartum care, heifer-calf pairs were placed in individual stalls for 24 hours, with fresh straw, feed and water. Upon completion of the 24 hour sampling of the calf, the pair was released into a post-calving pasture. The last two samples from the calves were taken in the pasture.

Blood samples were prepared and analyzed for; pack cell volume (PCV), differential white blood cell count (WBC), plasma cortisol and plasma triiodotyrosine (T_3). Statistical differences were determined by SAS analysis. All values are reported as means.

Results

Significant differences were not detected (P>.05) for breed of cattle or year of sampling. Thus, all heifer-calf pairs were grouped together for the statistical analysis.

Plasma cortisol concentrations, within birthing heifers, were significantly greater (P<.03) for those animals requiring severe mechanical pull or cesarean section, relative to heifers needing no assistance in the delivery of their calf (Figure 1). Statistical differences were also noted for heifers requiring modest mechanical assistance (less than 10 minutes) and those undergoing C-section (P<.05). It is important to note C-sections were preformed after failure to deliver the calf with mechanical assistance. Clearly those heifers requiring extensive mechanical assistance and/or surgical intervention were undergoing an acute stress, as is evident from the elevated cortisol values. Cortisol concentrations were not statistically different for heifers delivering bull versus heifer calves (Figure 1).

Cortisol, the stress indicator so identifiable in the heifer and clearly associated with the degree of calving difficulty,

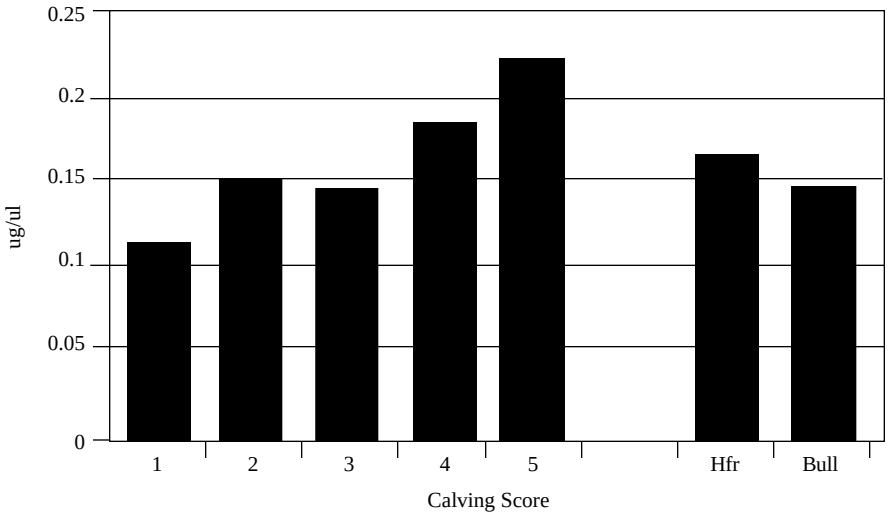

Figure 1. Concentration of cortisol in heifers at parturition as effected by the degree of calving difficulty and by calf sex. (P<.03; 1 vs. 4 & 5. P<.05; 2,3 vs. 5).

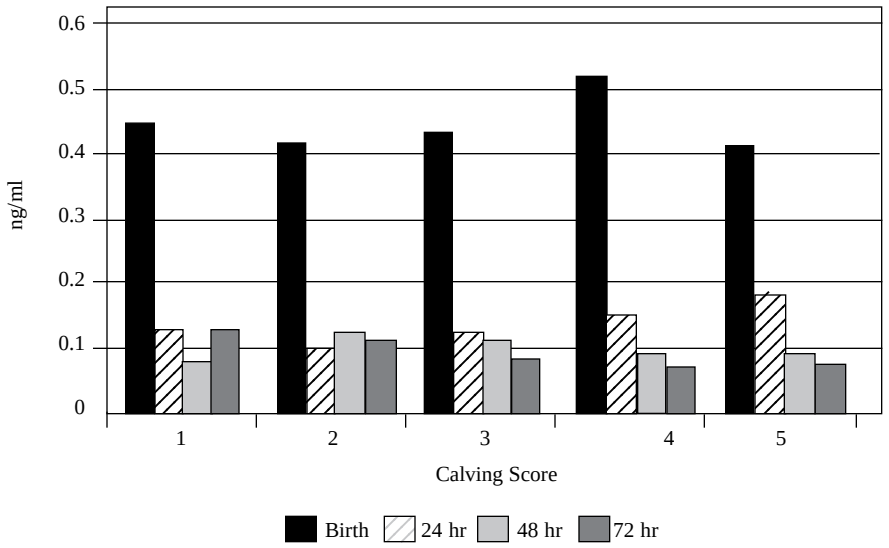

Figure 2. Concentration of cortisol in calves at birth and at 24, 48 and 72 hours of age as effected by the degree of calving difficulty. (Birth; P<.08; 1,2,3 vs. 4. 72 hrs; P<.07; 1 vs. 4,5).

was also in high concentrations within the calf population at the time of parturition (Figure 2). Cortisol values for the calf at parturition were higher (P<.08) in those calves delivered using more adverse procedures (i.e. severe mechanical pull versus hand or modest mechanical pull). It is important to note that high levels of cortisol are a favorable endocrine response for the newborn calf, considering the multiple rolls cortisol plays in the early survival of that calf. While cortisol's stress defense mechanisms are short-lived, and fall off rapidly within the first 24 hours of life (Figure 2), it does appear to maintain a slightly elevated concentration in those calves from difficult births. Calves requiring little or no assistance at birth maintained a reasonably constant plasma cortisol concentration during the three days following parturition. Calves requiring mechanical or surgical intervention, however, experienced a continual decline in cortisol values such that they were considerably less than unassisted calves at 72 hours postpartum (P<.07). The lower cortisol val-

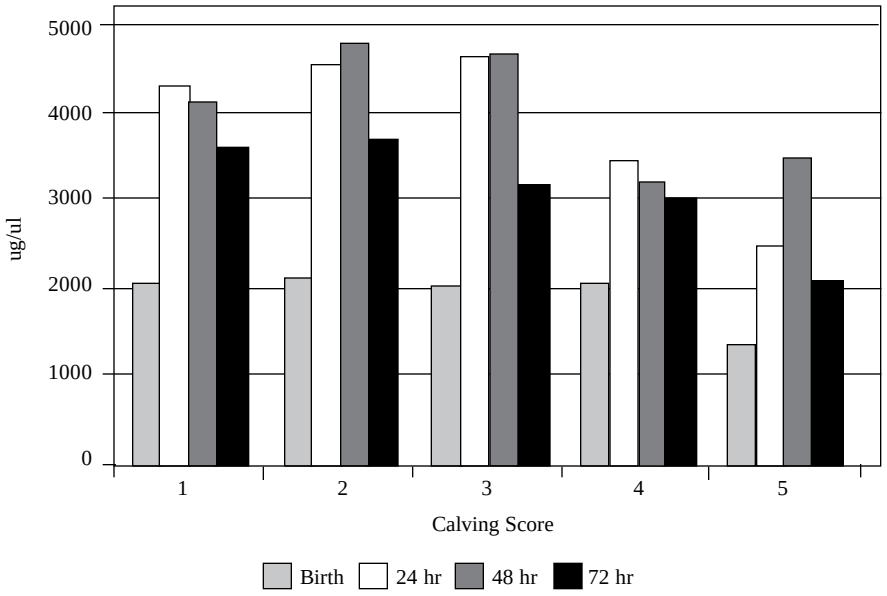

Figure 3. Concentration on T_3 in calves at birth and at 24, 48 and 72 hours of age as effected by the degree of calving difficulty. (Birth; P<.05, 1,2,3,4 vs. 5. 24 hrs; P<.02, 1,2,3 vs. 4,5. 48 hrs; P<.06, 1,2,3 vs. 4. 72 hrs; P<.08, 1,2 vs. 5).

Table 2. Neutrophil:lymphocyte ratio for calves at the time of birth, and at 24, 48 and 72 hours postpartum.

Hours Postpartum	Calving Score 1	2	3	4	5
Birth[a]	2.39	1.26	1.77	2.34	1.59
24 hrs	1.98	1.49	2.20	1.81	1.04
48 hrs	0.99	1.10	0.91	1.07	0.44
72 hrs[b]	1.48	0.79	1.38	1.82	2.08

[a]P<.05, 1 vs. 2.
[b]P<.08 1,2,3 vs. 4 and 5

ues are of concern, if, in fact, those first three to four days of life are the critical time in a calf's survival.

The calf's long-term survival skills might better be viewed via the study of plasma triiodotyrosine (T_3) during neonatal life. T_3 sets the metabolic state of the animal, responding to both external and internal stress factors (e.g. climatic changes, body size, brown fat thermogenesis and muscular, circulatory and respiratory activities of the body). There were no differences in T_3 among calving scores at the time of parturition (Figure 3), and presumably no difference in the metabolic state of calves derived with or without mechanical intervention. The exception to this was the cesarian born calves (P<.05). Physiologically, within the first 24 hours T_3 values should be increasing. However, calves born via severe mechanical pull or C-section exhibited a marked reduction in circulating thyroid hormone (P<.02), relative to unassisted delivery or modest assistance. The depressed T_3 is concerning when considering the January/February calving dates, the harsh environmental temperatures during this period and the critical need for body heat and muscular activity of the newborn calf.

Furthermore, knowledge of T_3 activity indicates the thyroid gland takes several days to respond to environmental stress. And T_3, unlike cortisol, is a long-term stress "adaptation mechanism", rather than an immediate defense response. Because of this, it is expected that on the third or fourth day of life, T_3 levels should be high. Once again, as with the cortisol values, calves delivered via severe mechanical pull or C-section exhibited a depressed endocrine response in association with the stress of parturition (Figure 3).

Like cortisol and T_3, the neutrophil:lymphocyte ratio (N:L) derived from the WBC count has been used extensively as an indicator of stress and morbidity. Neutrophils (phagocytic cells) increase in numbers during an acute stress, are short-lived and are considered stress defense cells. Conversely, lymphocytes (immune response cells) respond more slowly, exist in circulation longer, and are considered stress adaptation cells. While statistical differences were generally not noted during the early periods (Table 2), at 72 hours postpartum the N:L ratio was significantly higher (P<.08) for those calves derived via severe mechanical pull or C-section, relative to the unassisted or modest assistance calves. As with cortisol and T_3, the high N:L ratio clearly suggests calves of difficult birth are exhibiting a stress defense response (high neutrophils) and have yet to adapt to their new environment (low lymphocyte).

The significance of this research indicates the degree of calving difficulty has a pronounced effect upon that calf's ability to adapt to its new environment. Those calves requiring extensive mechanical assistance and/or surgical intervention express depressed cortisol and neutrophil values necessary for the immediate adjustment to their new environment. Their survival skills are further compromised via depressed metabolic adaptation capabilities (i.e. reduced T_3 and low lymphocyte concentrations) essential for that calf's first few days of life.

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Effect of Summer Grazing on Crude Protein and Digestibility of Winter Diets of Cattle in the Nebraska Sandhills

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Patrick Reece[1]

Year and winter sampling date significantly affect quality of winter diet samples from sandhills range, whereas summer stocking rate and date of summer grazing do not have a large impact.

Summary

Twenty-one pastures (three pastures/treatment) were used in a two-year study to determine the effects of summer grazing on winter diet quality of Sandhills range. Summer grazing treatments consisted of no summer grazing (control) and June or July grazing at three stocking rates. After summer grazing, pastures were then diet sampled using esophageally fistulated cows in November, January and March following summer treatments. Year and sampling date had a significant effect on CP and IVDMD of winter range diets, whereas summer grazing treatments did not have a large impact.

Introduction

Rotational grazing is a prevalent range management practice in the Nebraska Sandhills. Many ranches employing rotational grazing graze pastures one or more times during the spring and summer and graze residual/regrowth forage in the winter. The nutritional value of winter forage is variable, not well-defined and may vary with date and/or amount grazed during the growing season.

Winter diets of cattle on Sandhills range are usually less than 6% CP. Due to this low quality relative to cattle needs, winter grazing is normally coupled with protein supplementation. Lack of data describing winter diet quality variability and factors relating it to present difficulty in balancing supplementation needs with basal range diet quality. Since both over- and under-feeding of supplement can be costly, it is important to characterize winter diet quality as affected by summer grazing management.

The objective of this research was to determine the effects of June or July grazing at four levels of forage removal on the chemical composition and digestibility of sandhills winter range diets.

Procedure

In this study, 21 upland native range pastures, 2.47 acres each, were used at Gudmundsen Sandhills Laboratory. During the growing seasons of 1995 and 1996, seven grazing treatments were applied to these pastures (three pastures/treatment). Treatments consisted of a control with no summer grazing and June or July grazing at three stocking rates each. Stocking rates were 33, 67 and 100% of the stocking rate (.6 AUM's/acre) recommended for the upland range site where the study pastures are located.

Following summer grazing, pastures were winter diet sampled using two esophageally fistulated cows per pasture. Diet samples were obtained after allowing cows to graze each pasture for 45 minutes. Sampling dates for both study years were early November, early January and late March. After diet samples were freeze-dried and ground, the two samples obtained from each pasture were composited on an equal weight basis. Composited samples were then analyzed for CP and IVDMD.

Results

Table 1 shows the CP levels and digestibility of November, January and March diets from the two years of the study. There was a year "x" sampling date interaction ($P < .005$) which is reflective of different CP changes over sampling dates in year 1 relative to year 2. Lower CP in January diets compared to other sampling dates in year 1 may have been due to snow cover affecting the cows' ability to select a higher-quality diet. There was also snow cover offering a possible explanation for the lower observed CP in both January and March of year 2. Digestibility of winter

Table 1. Crude protein content and digestibility by year and month of winter diet samples from sandhills range, DM basis.

	Winter 1995-96			Winter 1996-97		
	Sampling date					
Item	Nov	Jan	Mar	Nov	Jan	Mar
CP[a]	6.5	6.0	7.0	5.5	4.7	4.2
IVDMD[b]	55.9	55.1	55.0	52.7	52.2	53.3

[a]Year x sampling date interaction ($P < .005$).
[b]Year main effect ($P < .05$).

Table 2. Crude protein and digestibility of winter diet samples from sandhills range listed by summer grazing treatment, DM basis.

	Control	June grazed			July grazed		
		Stocking rate[a]					
Item	0	33	67	100	33	67	100
CP	5.4	5.6	5.7	5.5	5.5	6.0	6.0
IVDMD[b]	55.1	54.4	54.3	53.9	53.8	53.1	53.7

[a]Percentage of recommended annual stocking rate (e.g. % of .6 AUM's/acre).
[b]Control vs. grazed (P = .09).

diets was affected (P < .05) by year but was not affected by winter sampling time.

In Table 2, mean crude protein and digestibility values are listed by summer treatment. Diets collected from control pastures tended to be higher (P = .09) in digestibility than pastures grazed during the summer. There were no significant summer treatment effects on CP levels in winter diets.

Summer grazing treatments did not have a significant impact on winter diet quality of Sandhills range. However, year-of-winter sampling caused variation in CP and digestibility and month-of-winter sampling affected CP of winter diet samples. Small differences in chemical composition, especially CP, could have a notable effect on supplementation and cow performance over a winter grazing season. The variation in CP and IVDMD observed in this study is evidence that winter diet quality is not static and is an important management consideration.

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Ruminal Degradation of Rubisco by Beef Cattle Grazing Switchgrass and Big Bluestem

Dan Vaughn
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Lowell Moser
Robert Graybosch
Terry Klopfenstein[1]

Passage of bundle sheath cells in warm-season grasses from the rumen appears to be a mechanism allowing proteins to escape rumen degradation.

Summary

This two-year study was conducted on monocultures of switchgrass and big bluestem to: (1) determine the concentration of the protein ribulose-1,5-bisphosphate carboxylase (Rubisco), found only in the bundle sheath cells of warm-season grasses, in omasal, masticate and fecal samples of grazing cattle; and (2) estimate rumen-escape Rubisco via bundle sheath cells. A quantifying enzyme-linked immunosorbent assay, along with estimates of rumen and lower tract digestibilities, indicated as much as 11% of Rubisco in big bluestem and 13% in switchgrass escaped rumen degradation and was absorbed in the lower tract. Realizing these amounts of escape Rubisco represent a significant level of soluble protein, bundle sheath cells may provide a mechanism allowing soluble protein to escape ruminal degradation.

Introduction

Significant amounts of dietary protein in warm-season grasses pass from the rumen undegraded and are digested and absorbed in the lower tract. Previous research indicates bundle sheath cells in warm-season grasses may play a role in protein escape from the rumen. In warm-season grasses, Rubisco, the enzyme responsible for CO_2 fixation in C3 photosynthesis, is located exclusively in bundle sheath cells. In previous research, Rubisco was detected in omasal and fecal samples from cattle grazing monocultures of switchgrass or big bluestem. This past research hypothesized that a portion of the ingested Rubisco and associated proteins escape the rumen via bundle sheath cells which are structurally weakened by rumen activity. They proposed the proteins are digested in the lower tract following further degradation of the weakened bundle sheath cells. The hypothesis has not been verified, nor has the amount of Rubisco escaping the rumen or disappearing in the lower tract been estimated.

The purpose of this study was to determine if passage of bundle sheath cells from the rumen represents a mechanism for protein to escape from the rumen. The specific objectives were to (1) determine the concentration of Rubisco in masticate, omasal and fecal samples of ruminally-fistulated beef cattle grazing switchgrass and big bluestem; and (2) estimate rumen-escape Rubisco via bundle sheath cells. Presence of Rubisco in a sample would indicate presence of intact bundle sheath cells, as the highly soluble Rubisco is found only in bundle sheath cells of warm-season grasses.

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Procedure

Monocultures of switchgrass and big bluestem were grazed in the summers of 1995 and 1996 at the University of Nebraska Agricultural Research and Development Center near Mead, Nebraska. Each pasture was grazed by three ruminally fistulated cows (1,350 lb) in 1995 and four ruminally fistulated steers (650 lb) in 1996. Pastures were grazed at vegetative and late elongation/early reproductive stages for each grass species. Cattle strip-grazed each pasture at each stage of development for six days and samples were collected on day 7. Animals were moved daily and herbage allowance on the switchgrass and big bluestem monocultures remained above 330 lbs AUD^{-1} in 1995 and above 440 lbs AUD^{-1} in 1996.

Rumen contents of each animal were evacuated and samples of the omasal contents were obtained by hand through the reticulo-omasal opening on day 7. Before replacing the rumen contents, masticate samples were collected after a 30-minute grazing period to represent the undegraded forage being grazed. Fecal samples also were obtained on day 7 of the grazing period.

Sodium dodecyl sulfate polyacrylamide gel electrophoresis (SDS-PAGE) along with a western immunoblotting procedure were used to determine the presence of Rubisco in the masticate, omasal and fecal samples. Enzyme-linked immunosorbent assay analysis was performed to quantify Rubisco concentrations.

Dry Matter Disappearance

Dry matter loss in the rumen and lower tract of the animal was estimated for calculation of Rubisco disappearance at the two points in the digestive tract. Acid insoluble ash (AIA) was used as an internal marker for estimation of digestibility. Percentage dry matter disappearance (DMD) in the rumen and lower tract was calculated using the following equations.

DMD in rumen = 100 - 100 (% AIA masticate sample / % AIA omasal sample)

DMD in lower tract = 100 - 100 (% AIA omasal sample / % AIA fecal sample)

Calculations of Rumen-Escape Rubisco

Rumen-escape Rubisco, or Rubisco disappearing in the lower tract (%RE RuBPCase), was calculated (± S.E.) as a percentage of total Rubisco using the following equation:

$$\% \text{ RE Rubisco} = \frac{(OR \times 1 - RD) - (FR \times 1 - RD \times 1 - LD)}{MR}$$

where OR is omasal Rubisco concentration, RD is rumen digestibility, FR is fecal Rubisco concentration, LD is lower tract digestibility and MR is masticate Rubisco concentration. The equation accounts for dry matter (DM) loss in the rumen and lower tract so the estimate of percentage rumen-escape Rubisco is based on intake Rubisco.

Concentrations of Rubisco escaping the entire digestive tract (%TE Rubisco) was estimated (±S.E.) as a percentage of total Rubisco using the following equation:

$$\%\text{TE Rubisco} = \frac{FR \times (1 - RD) \times (1 - LD)}{MR}$$

where FR is fecal Rubisco concentration, RD is rumen digestibility, LD is lower tract digestibility and MR is masticate Rubisco concentration. Fecal Rubisco concentrations represent the percentage of intake Rubisco found in the feces.

Results and Discussion

Extraction of N-containing substrates from the switchgrass and big bluestem samples was very effective. Over 97% of the N was extracted consistently from the masticate, omasal and fecal samples. Rubisco was detected in undegraded leaf, masticate and omasal extracts of switchgrass and big bluestem by western immunoblotting following SDS-PAGE. Negligible amounts of Rubisco were detected in the fecal extracts of switchgrass and big bluestem. Identification of Rubisco in omasal samples of big bluestem and switchgrass verified previous research results.

Concentrations of Rubisco in masticate, omasal and fecal samples (Table 1) were used in conjunction with estimates of DM loss in the rumen and lower tract to calculate Rubisco disappearance in the rumen and lower tract (Table 2). Disappearance of big bluestem Rubisco in the rumen was between 63.6% and 65.3%, except in the 1996 vegetative stage. Percentage switchgrass Rubisco disappearing in the rumen was 15 to 25% lower than for big bluestem, except for the 1996 vegetative samples. Percentage switchgrass Rubisco disappearance of the 1996 vegetative samples was nearly two-fold higher than the other switchgrass samples. The relatively high amounts of Rubisco disappearing in the rumen for the switchgrass and big bluestem vegetative samples in 1996 cannot be explained.

Disappearance of Rubisco in the lower tract ranged from 10.6% to 19.5% for big bluestem and 13.3% to 39.6%

Table 1. Percentage Rubisco concentrations (±S.E.) in omasal, masticate and fecal samples of beef cattle grazing big bluestem or switchgrass in vegetative or elongation/reproductive stages of growth.

	Vegetative		Elongation/Reproductive	
Species	1995	1996	1995	1996
	%			
Big bluestem				
Omasal	2.9 (.06)	5.0 (.30)	3.7 (.28)	4.3 (.28)
Masticate	3.9 (.26)	11.9 (3.0)	5.2 (.96)	6.6 (.96)
Fecal	3.2 (.16)	3.2 (.24)	4.2 (1.3)	2.6 (.20)
Switchgrass				
Omasal	4.6 (.12)	3.5 (.20)	4.8 (.16)	4.6 (.38)
Masticate	5.5 (.70)	12.3 (2.8)	5.0 (.10)	7.2 (2.2)
Fecal	4.1 (.16)	1.5 (.26)	4.4 (.16)	2.1 (.28)

Table 2. Percentage intake Rubisco (±S.E.) disappearing in the rumen and lower tract, and escaping the entire digestive tract of beef cattle grazing big bluestem or switchgrass in vegetative or elongation/reproductive stages of growth.

	Vegetative		Elongation/Reproductive	
Species	1995	1996	1995	1996
	%			
Disappearing in rumen				
Big bluestem	63.6 (3.4)	80.8 (6.8)	65.3 (13.3)	63.8 (9.0)
Switchgrass	49.6 (9.6)	84.1 (2.3)	39.3 (8.9)	47.9 (9.4)
Disappearing in lower trace				
Big bluestem	14.4 (.42)	10.6 (2.4)	14.7 (5.7)	19.5 (5.3)
Switchgrass	21.7 (8.9)	13.3 (2.4)	27.1 (3.8)	39.6 (.54)
Escaping entire trace				
Big bluestem	22.2 (3.0)	9.1 (3.4)	19.9 (7.6)	14.2 (2.3)
Switchgrass	28.7 (1.0)	4.8 (.9)	33.5 (6.0)	21.8 (3.2)

for switchgrass over stages of growth and years. Disappearance of Rubisco in the lower tract indicates a significant portion of ingested bundle sheath cells escape the rumen to be degraded in the lower tract. Bundle sheath cells entering the lower tract may be structurally weakened due to rumen activity and their contents, including Rubisco, may become available to digestive enzymes in the lower tract. Mean percentages of Rubisco escaping the entire digestive tract were above 10% for both species, except for the 1996 vegetative samples. A portion of bundle sheath cells apparently escaped the entire digestive tract.

Our results indicate a significant part of intake Rubisco escapes rumen degradation via bundle sheath cells and disappears in the lower tract. The Rubisco, which we used as a marker of bundle sheath cell integrity, represents only a portion of the available protein in bundle sheath cells. Because concentration of Rubisco in bundle sheath cells has not been determined for switchgrass and big bluestem, we cannot accurately estimate amount of protein escaping the rumen via these cells. Composition of bundle sheath cells and total soluble protein relative to Rubisco, however, has been determined for such warm-season, agronomic grasses as corn and millets. For example, we used the Rubisco concentrations in millet, along with our values of rumen-escape Rubisco, to determine if the amount of rumen-escape protein via bundle sheath cells was biologically significant. Estimates of rumen-escape protein ranged from 7% to 32% of the total crude protein content for switchgrass and 7% to 14% for big bluestem. Rumen-escape protein estimates were lower for the vegetative stage and higher for the elongation/reproductive stages. Our estimates of escape protein via bundle sheath cells are about 50% less than estimates of total rumen-escape protein for big bluestem and switchgrass reported in the literature. Our values are low compared to other estimates partially because we are not accounting for the non-bundle sheath cell protein that escapes. However, our example calculations indicate that the bundle sheath cell mechanism may account for as much as 50% of the rumen escape protein in big bluestem and switchgrass.

In conclusion, passage of bundle sheath cells from the rumen appears to provide a mechanism which allows protein escape from the rumen. Also, our results indicate Rubisco and associated proteins found in a portion of the escaping bundle sheath cells disappear in the lower tract. The amount of Rubisco and associated proteins escaping the rumen via bundle sheath cells could represent a significant portion of rumen-escape protein in big bluestem and switchgrass. Understanding the mechanisms involved in rumen escape protein should improve the efficiency of livestock feeding systems and assist in the selection of improved forage species.

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Evaluating Stress in Calves Weaned at Three Different Ages

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Calves weaned in October (210 days) exhibited less chronic stress, more prolonged endocrine responses, and greater weight gains than calves weaned in August (150 days) and December (270 days).

Summary

Trials were conducted to evaluate the effects of weaning calves at 150, 210 and 270 days of age (i.e. August, October and December, respectively). A total of 75 Angus x MARC II heifers calves were used in this study. Heifers were bled on the day of weaning and again at 2, 7, 14 and 28 days after weaning. Blood was analyzed for differential WBC, cortisol, T_3 and glucose. Weight changes were recorded. The data suggests October weaned calves (210 days) had both greater blood cortisol and glucose at days 7, 14 and 28 post-weaning and greater weight gains when compared to calves weaned at 150 and 210 days of age.

Introduction

Cattle, which are animals of habit, become stressed when they experience a novel or painful situation. Weaning can be one such stressful change. Weaning involves not only psychological

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stress due to separation, but also abrupt changes in the calf's environment, nutrition and social structure. Because of these variables, weaning could result in a considerable setback in a calf's performance.

Studies on cattle suggest the physiological effects of separating a calf from its mother may contribute to a performance decrease several days after weaning. Physiological effects may be classified into three general categories; gross clinical signs, blood composition changes and endocrine interposed changes.

The initial response to stress is a release of hormones from the adrenal gland. The adrenal hormone cortisol functions to increase gluconeogenesis resulting in increased blood glucose, decreased glucose uptake by the tissues, decreased protein synthesis and an increased immune-defense system (increase in WBC count).

Triiodothyronine (T_3) responds to stress by calibrating the metabolic state of the animal, which means body heat production is altered, allowing the stressed animal to adapt to the environment. Thus, both rapid defense systems (cortisol) and long-term adaptation mechanism (T_3) are effected by stress.

In this study, cortisol, T_3, glucose, differential WBC and weight changes were analyzed to determine the effects of weaning at 150, 210 and 260 days of age.

Procedure

Animals and management

This research was conducted using 75 Angus x MARC II crossbred heifer calves. All animals were managed at the University of Nebraska, Dalbey-Halleck Farm near Virginia, Nebraska. Calves were randomly allotted to one of three weaning groups based on age (150, 210 and 260 days; August, October and December weaning, respectively). In addition, control groups of non-weaned calves were assigned to August and October weaning groups. At weaning, all calves were separated from their dams and taken to a post-weaning pen with free access to grass hay and water. After three days they were fed corn and a protein supplement to gain 1.25 to 1.5 pounds per day. The non-weaned calves remained with their mother.

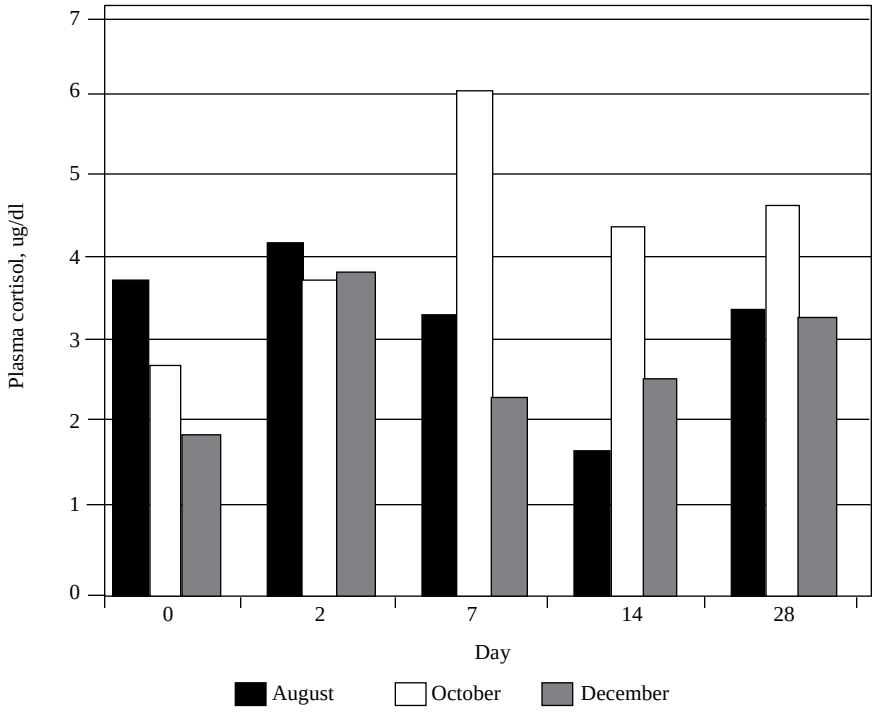

Figure 1. Plasma cortisol means observed in the calves at the day of weaning and at 2, 7, 14 and 28 days after weaning for August, October and December groups.

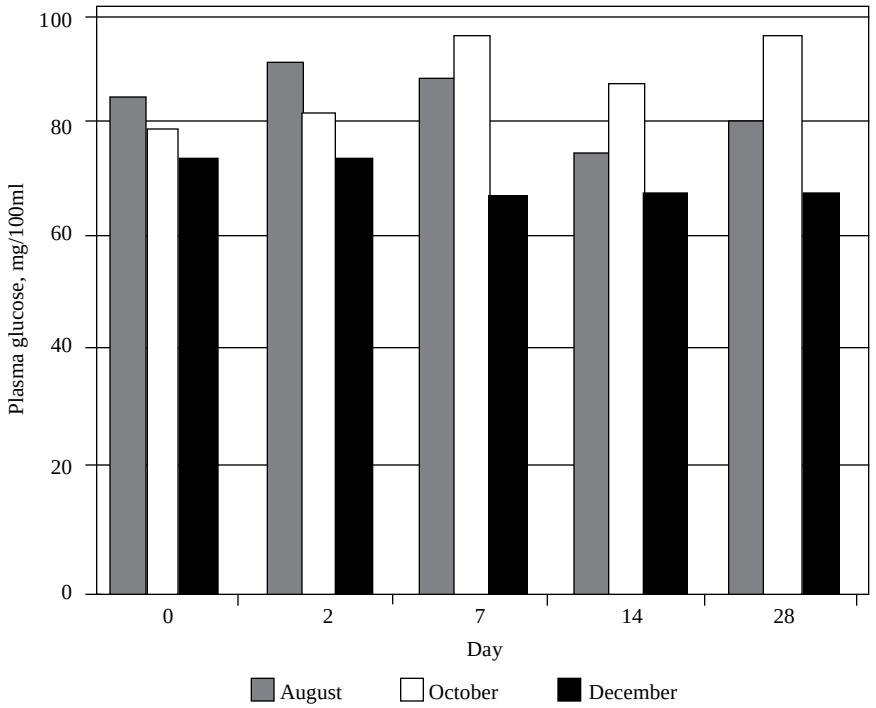

Figure 2. Plasma glucose means observed in the calves at day of weaning and at 2, 7, 14 and 28 days after weaning for August, October and December groups.

Blood sampling

Blood samples were collected via jugular venipuncture on the day of weaning (day 0) and days 2, 7, 14 and 28 after weaning from both weaned and non-weaned calves. Plasma samples were analyzed for T_3 and cortisol, using radioimmunoassay and glucose, and using automated, colorimetric determination (Auto Analyser I). Blood smears were

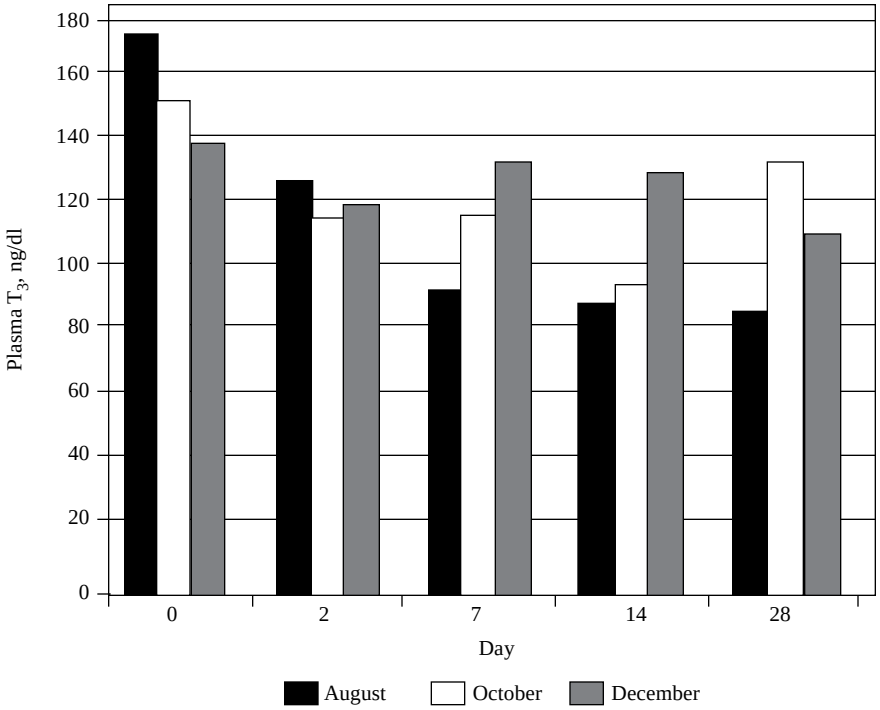

Figure 3. Plasma T_3 means observed in the calves at the day of weaning and at 2, 7, 14 and 28 days after weaning for August, October and December groups.

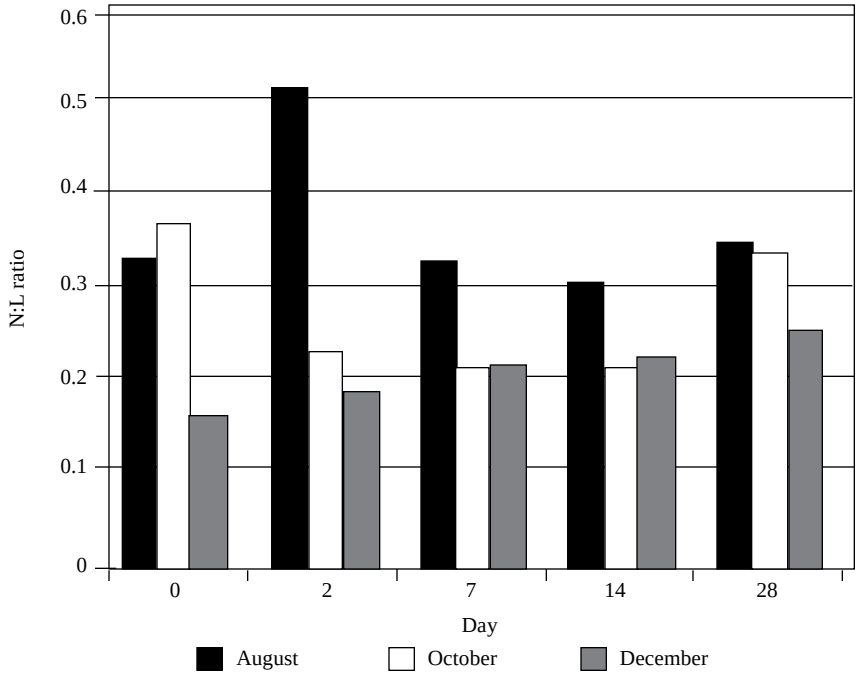

Figure 4. Neutrophil:Lymphocyte ratio means observed in the calves at the day of weaning, and at day 2, 7, 14 and 28 after weaning for August, October and December groups.

made from each sample to determine differential white blood cell counts.

Results and Discussion

Significant differences (P<0.01) existed for most blood parameters due to age of weaning. Mean values for each blood parameter are presented in Figures 1 through 4. Non-weaned calves presented no significant changes in the concentration of the blood parameters analyzed over the 28-day trial. Plasma cortisol increased for October and December weaned calves at day 2 post-weaning (P<0.001), but continued to increase and remain high only in October-weaned calves (P<0.01- Figure 1). Plasma cortisol values decreased at days 7 and 14 for the August weaned calves (P<0.05). Plasma glucose concentration changes were not as dramatic as those of cortisol (Figure 2). Blood glucose concentrations for October calves continued to increase and remain high throughout the post-weaning period, while concentrations for August and most noticeably December weaning decreased.

Concentrations of plasma T_3 were highest in the August and lowest in the December calves at the time of weaning (P<0.05 - Figure 3). Plasma T_3 decreased (P<0.05) in each age group, but were similar at day 2 post-weaning. Thereafter, post-weaning concentrations of T_3 were generally reflective of the environmental temperature during that post-weaning period. Calves weaned in the warm August days maintained the lower T_3; calves weaned in December exhibited higher T_3 concentrations.

Figure 4 presents the data for the Neutrophil: Lymphocyte ratio (WBC count). Calves weaned in August demonstrated the most dramatic increase in N: L ratio at day 2 post-weaning (P<0.05), and continued to maintain the higher ratio throughout the post-weaning period. The October and December weaned calves had similar, but lower, N: L ratio's during the post-weaning period.

Figure 5 illustrates the weight gain of the calves from weaning (day 0) to the completion of the trial (day 28) for each age group, as well as for the control (non-weaned) calves. Mean weight gains were greater (P<0.05) for October (67.5 lb) weaned calves compared to August (52.2 lb - P<0.1) and December (43.7 lb) weaned calves for the first 28 days post-weaning.

We know stress response increases the animals resistance to stress. The overall effects of stress can be favorable or not, depending on the animal's perceptions. In an acute stage, the stress response is, in general, beneficial. On

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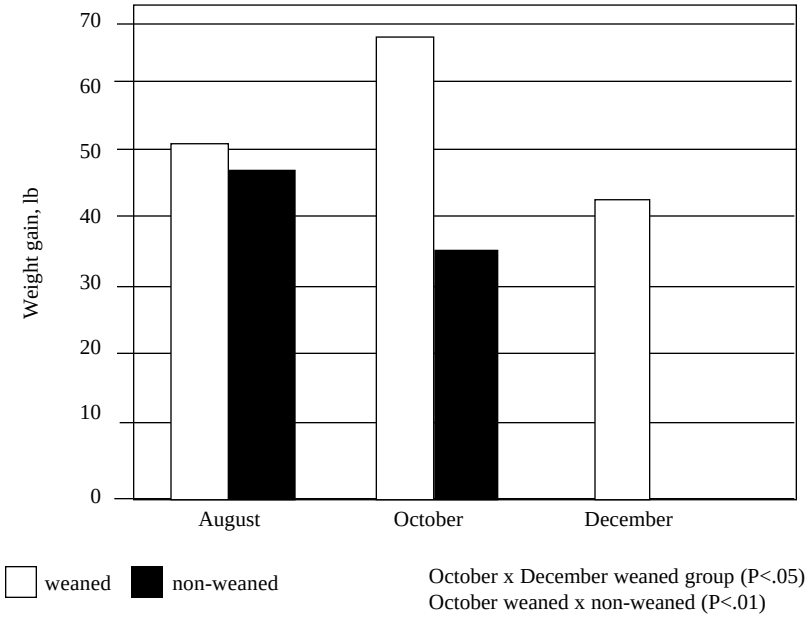

Figure 5. Changes in weight observed in weaned and non-weaned calves in August, October and December groups.

the other hand, if the stress is too intense, it may be harmful to the calves. In this study, calves weaned in October (210 days) had higher concentrations of cortisol and glucose on days 7, 14 and 28 after the weaning; however weight gain was significantly greater in this group of calves compared to calves weaned in August (150 days) and December (270 days). Therefore, for October-weaned calves, the stress was not severe enough to decrease animal performance and actually induced a favorable response increasing their weight gains as compared with the other two groups.

[1]Andrea Bueno, Todd Cappel and Chuck Story, graduate students. Rick Rasby and Edd Clemens, Professors, Animal Science, Lincoln; Mark Dragastin, manager, Dalbey-Halleck Research Farm, Virginia.

Induction of Estrus in Anestrous Suckled Beef Cows

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Anestrous beef cows can be induced to initiate estrous cycles postpartum by short-term treatment with an intravaginal implant of progesterone.

Summary

Suckled anestrous beef cows (n=362) received either: 1) an intravaginal implant containing progesterone for 7 days plus a 1 mg injection of estradiol benzoate 24 to 30 hours after implant removal; 2) an intravaginal implant containing progesterone for 7 days; 3) a sham implant for 7 days plus a 1 mg injection of estradiol benzoate 24 to 30 hours after implant removal; or 4) a sham implant for 7 days. Treatment with progesterone resulted in resumption of luteal function in suckled anestrous beef cows with most cows developing corpora lutea with a typical lifespan, whereas treatment with estradiol benzoate enhanced the expression of estrus.

Introduction

Treatment with progestins, such as melengestrol acetate, norgestomet or progesterone (P_4) induces estrous cycles in some anestrous cattle. Progestin pretreatment alters uterine function after the first postpartum ovulation and yields normal duration of luteal function. Treatment with estradiol benzoate (EB) following progesterone withdrawal enhances incidence of ovulation in postpartum cows.

The objectives of this experiment were to determine whether: 1) treatment with progesterone via an intravaginal implant induces estrus and formation of corpora lutea (CL) with typical lifespans; and 2) treatment with estradiol benzoate (EB) following progesterone removal improves rates of behavioral estrus and formation of CL with typical lifespans in suckled anestrous beef cows.

Procedure

Suckled anestrous beef cows (n=362) from 25 to 50 days postpartum were used in four locations (Montana, n=97; Nebraska, n=101; Ohio, n=92; and West Virginia, n=72). On average, cows were in their third parity during the experiment. Within each location, cows were stratified by calving date and assigned to receive one of four treatments. Beginning on day 0 (day of treatment initiation) cows were treated with one of the following: 1) an intravaginal implant containing P_4 (EAZI-BREED™ CIDR®, InterAg, Hamilton, New Zealand) for 7 days plus an injection of 1 mg of EB (CIDIROL®, InterAg, Hamilton, New Zealand) 24 to 30 hours after progesterone removal (P_4 + EB); 2) an intravaginal implant containing P_4 for 7 days (P_4); 3) a sham implant for 7

days plus an injection of 1 mg of EB 24 to 30 h after device removal (EB); or 4) a sham implant for 7 days (control). The intravaginal implant contained 1.9 g of P_4 and was designed to release amounts of P_4 typical of the concentration found circulating during the luteal phase of the estrous cycle.

Body condition scores, based on a 1 to 9 scoring system (1 = thin and 9 = fat), were assessed for each animal on the day of implant insertion. Mean body condition scores of cows within each location were: Montana, 4.6; Nebraska, 4.1; Ohio, 4.7; West Virginia, 5.0.

Blood Collection and Response to Treatment

Blood samples were collected on day -7, 0, 8, 15 and 22 (day 0 = implant insertion) via the jugular or tail vein and were used to assess circulating concentration of P_4 as an indicator of luteal function. Based on changes in concentration of P_4 during the experiment, cows were fitted into one of the following response categories: 1) anestrus, 2) typical lifespan CL, 3) short-lived CL, 4) late CL (CL formed late in experiment; not in response to treatment) and 5) early CL (CL formed early in experiment; not in response to treatment).

Behavioral Response to Treatment

To detect onset of behavioral estrus, cows were observed for at least 30 minutes twice daily at approximately 12-hour intervals from day 0 to day 22 of the experiment. Data were placed into one of the following three categories according to behavioral activity: 1) standing estrus, receptive to mounting by other cows; 2) active, cows exhibited sexual activity but would not stand to be mounted; or 3) no estrus, cows did not exhibit any signs of behavioral estrus. Only data from day 0 to day 11 of the experiment regarding behavioral response to treatment were analyzed, with day 9 to day 11 being the period when the majority of behavioral responses to treatment were expected to occur.

Conclusions from this experiment could potentially alter current management scenarios of cow-calf producers. Ultimately, producers are interested in the number of cows exhibiting estrous cycles at the onset of the breeding season and its effect on reproductive efficiency. Therefore, a table of predicted data was compiled and analyzed in which numbers of cows that had formed CL by various criteria, reflecting effects of treatment and natural resumption of estrous cycles, were considered.

Results and Discussion

Response to Treatment

The proportion of cows forming CL with a typical lifespan increased ($P < .001$) in response to treatment with P_4 (Table 1), but location, body condition score, parity and number of days during the postpartum period had no effect. There were no interactions among treatments or location affecting formation of CL with a typical lifespan.

Behavioral Response to Treatment

The proportion of cows exhibiting estrus (i.e. standing estrus or estrous activity) from day 0 to day 11 increased ($P < .05$) in response to P_4 treatment (Figure 1). Similarly, EB increased ($P < .001$) the proportion of cows exhibiting estrus (Figure 1). Body condition score, parity and number of days during the postpartum period did not affect the proportion of cows exhibiting estrus. However, there was an effect ($P < .05$) of location on proportion of cows detected in estrus. There were no interactions between P_4 and EB, location and P_4 or location and EB on the incidence of estrus. The majority of cows exhibiting estrus activity did so from day 9 to day 11 of the experiment; few cows exhibited estrus activity during the treatment period from day 0 to day 8 (Figure. 1).

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Table 1. Proportions of cows within each treatment that either formed a corpus luteum or did not initiate luteal function.

	Treatment			
Response[a]	P_4+EB	EB	P_4	Control
Anestrus	15/93 (16%)	29/86 (34%)	28/92 (30%)	31/91 (34%)
Typical lifespan CL	66/93 (71%)	17/86 (20%)	51/92 (55%)	15/91 (16%)
Late CL	0/93 (0%)	14/86 (16%)	0/92 (0%)	6/91 (7%)
Short-lived CL	4/93 (4%)	10/86 (12%)	5/92 (5%)	26/91 (29%)
Early CL	8/93 (9%)	16/86 (19%)	8/92 (9%)	13/91 (14%)

[a] Effect of the following variables on distribution of cows within response categories: P_4, $P < .001$; EB, $P > .10$; P_4 x EB, $P > .10$.

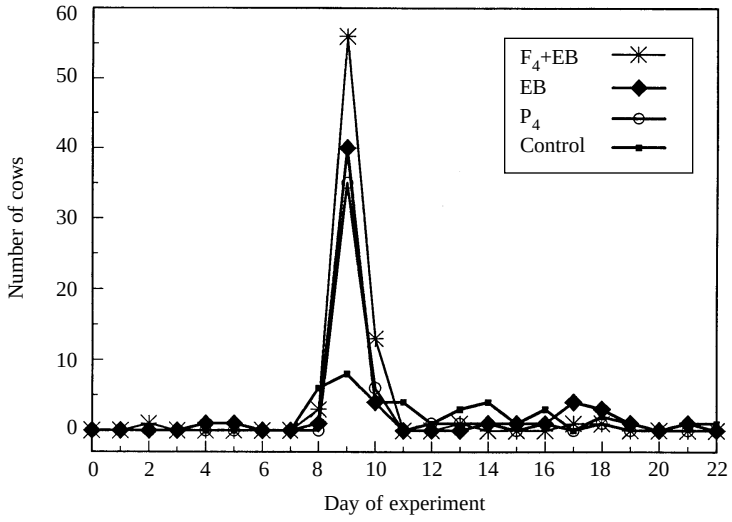

Figure 1. Number of cows within each treatment exhibiting estrous activity or standing estrus during the experiment. Day 0 = initiation of treatments with intravaginal implants.

Predicted Proportions

A greater proportion ($P < .01$) of cows treated with P_4 alone or in combination with EB were induced to form CL with a typical lifespan, compared with untreated cows (Table 2). The effect of P_4 was enhanced ($P < .01$) by EB, but EB alone tended to reduce ($P < .10$) the proportion of cows forming either a short-lived CL or CL with a typical lifespan, compared with untreated cows (Table 2). The combination of P_4 and EB increased the proportion of cows forming CL in response to or during treatment ($P < .01$) and the proportion that had formed CL by the end of the experiment ($P < .05$), compared with untreated cows (Table 2).

Our data reveal short-term treatment of anestrous cows with P_4 can induce earlier ovulation in some cows, increase the percentage of cows exhibiting estrous cycles during the breeding season and, presumably, increase the percentage of cows conceiving at first service. Because these treatments can be used to synchronize estrus in cows exhibiting estrous cycles, they provide the potential to artificially inseminate a large proportion of the herd at the same time.

Providing an exogenous source of estradiol (i.e., EB) increased the proportion of cows exhibiting signs of behavioral estrus. This estrus behavior was concentrated from day 9 to day 11 of the experiment (Figure 1). A greater proportion of cows treated with P_4 and EB were either active or exhibited standing estrus compared with cows treated with P_4 alone. While some cows in the control group may have been induced to exhibit estrous cycles by the concentrated estrous activity of treated cows, more exhibited estrus activity beyond day 11 (Figure 1).

Because estradiol induces the preovulatory LH surge causing ovulation, we expected treatment with EB in addition to P_4 would further increase the proportion of cows forming CL. However data analyzed in Table 1 showed EB did not enhance the response of progesterone in inducing onset of luteal function. From a practical standpoint, however, producers are interested in the number of cows exhibiting estrous cycles at the onset of the breeding season, which should enable more cows to become pregnant early in the season, resulting in fewer nonpregnant cows. Analyzing data as reported in Table 2 allows for the consideration that some cows would have initiated estrous cycles in the absence of progesterone treatment and compares the predicted effectiveness of each treatment with data for control cows in inducing luteal function by the end of the experiment. Based on the predicted data in Table 2, a greater proportion of cows treated with P_4 and EB would be expected to form short-lived or typical lifespan CL compared to untreated cows. Treatment with P_4 alone should increase the numbers of cows developing CL with typical or short lifespans. The data in Table 2 indicate treatment with both P_4 and EB should be more effective in inducing luteal function than other treatments. Combined treatment with P_4 and EB may induce an adequate preovulatory LH surge in a portion of cows with insufficient endogenous estradiol production, increasing the number of cows developing CL.

Treating postpartum beef cows during lactational anestrus with progesterone and estradiol benzoate induced estrus and the formation of corpora lutea with typical lifespans. These responses in anestrous cows can increase the percentage of cows exhibiting estrous cycles at the onset of the breeding season and may result in both more cows being maintained on a yearly calving interval and fewer cows being culled from the herd. Because these treatments can be used to synchronize estrus in cows, they provide the potential for artificial insemination of a large proportion of the herd at the same time.

Table 2. Predicted proportions of cows within each treatment group that formed a corpus luteum by various criteria.

	Treatment			
Response	P_4 +EB	EB	P_4	Control
Formed or would have formed a CL during P_4 treatment[a]	7	8	7	5
Formed a CL with a typical lifespan[b]	59/78 (76%)**	17/70 (24%)	44/77 (57%)*	15/78 (19%)
Formed a short-lived or typical lifespan CL[c]	63/78 (81%)**	27/70 (39%)†	49/77 (64%)	41/78 (53%)
Total cows that formed a CL by 4 d after the end of treatment[d]	78/93 (84%)**	43/86 (50%)	64/92 (70%)	54/91 (59%)
Total cows that formed a CL by end of experiment[e]	78/93 (84%)*	57/86 (66%)	64/92 (70%)	60/91 (70%)[a]

**Proportion differs from control: $P < .01$.
*Proportion differs from control: $P < .05$.
†Proportion differs from control: $P < .10$.
[a]Number of cows predicted to have formed a corpus luteum (CL) during treatment. Values for cows treated with sham devices were calculated from data for response 5 in Table 1. For EB, sham device (16/86) minus P_4 implant (8/93) = 8. For control, sham (13/91) minus P_4 (8/92) = 5. Value for P_4-treated cows was estimated as the mean of these values (6.5, rounded to 7).
[b]Proportion of cows that formed a CL with a typical lifespan. This proportion excludes from the denominator cows that were in metestrus at treatment initiation or that formed or were predicted to form a CL while carrying a device (Early CL).
[c]Proportion of cows that formed either a CL with a typical lifespan or a short-lived CL. Early CL response is excluded from the denominator.
[d]Proportion of cows in which a CL had formed by 4 d after the end of treatment.
[e]Proportion of cows that formed a CL by the end of the experimental period.

[1]Karol Fike, former graduate student; Michael Day, Associate Professor of Animal Science, Ohio State University; Keith Inskeep, Professor of Animal Science, West Virginia University; James Kinder, Professor of Animal Science, University of Nebraska; Paul Lewis, Professor of Animal Science, West Virginia University; Robert Short, Professor of Animal Science, USDA ARS, Livestock and Range Research Laboratory, Miles City, MT; Harold Hafs, Professor of Animal Science, Rutgers University.

A Novel Estrous Synchronization Program for Beef Cattle Using Melengestrol Acetate

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Estrous cycles can be synchronized among anestrous and estrual beef females by feeding melengestrol acetate for 18 days and injecting progesterone and estradiol 7 days before end of MGA feeding.

Summary

Estrous synchronization rate and conception and pregnancy rates to AI were evaluated following three estrous synchronization protocols for beef cattle. During 1995 and 1996, heifers and cows (n = 379) received either: 1) melengestrol acetate (MGA) for 18 days plus an injection of progesterone and estradiol in oil 7 days before end of treatment; 2) MGA for 17 days; or 3) two injections of $PGF_{2\alpha}$ 10 days apart. The greatest pregnancy rates (number conceived/number treated) among both anestrous and estrual females were achieved following treatment with MGA and an injection of progesterone and estradiol.

Introduction

Estrous synchronization programs in beef herds can condense labor during breeding and calving seasons as well as produce calves more uniform in weight. Programs incorporating progestins such as norgestomet, MGA and (or) progesterone can also induce estrous cycles in anestrous females. Treatment with commercially used doses of a progestin in the absence of corpora lutea results in development of persistent ovarian follicles. While reduced fertility is associated with ovulation of persistent ovarian follicles, fertility can be improved with short-term progesterone treatment to induce regression of persistent ovarian follicles.

Development of a relatively inexpensive estrous synchronization program limiting animal handling without compromising pregnancy rates (number females pregnant/number females treated) would benefit the beef industry. We hypothesized that estrous synchronization of beef females using MGA and an injection of progesterone and estradiol would maximize pregnancy rates as compared with use of MGA alone or two injections of $PGF_{2\alpha}$.

Procedure

Angus x Gelbvieh heifers (n = 52) and mature composite (MARC III; n=288) and Angus x Gelbvieh cows (n = 39) from the beef physiology herd were used during two years (1995 and 1996). Females were blocked by breed and were stratified by calving date and assigned to receive one of the following: 1) MGA (.5 mg/hd/day) for 18 days plus an injection of 200 mg progesterone and 1 mg estradiol in sesame oil on day 11 (MGA+P_4; day 0 = first day of MGA feeding); 2) MGA for 18 days plus an injection of sesame oil on day 11 (MGA); or 3) two injections of $PGF_{2a\alpha}$ (25 mg; Lutalyse® Sterile Solution, Upjohn, Kalamazoo, MI) on day 7 and 17 (PG).

During the experiment, females were maintained in bromegrass pastures. During 1995, 2 lb per animal of forage-based pellets containing MGA were fed with either range cubes or corn (1.5 to 2 lb/hd/day) for females in the MGA or MGA+P_4 treatment groups, while females in the PG treatment group received range cubes (3.5 to 4 lb/hd/day). Because feed consumption for females treated with MGA was inconsistent throughout the treatment period, mechanisms such as feeding molasses and keeping cattle off pasture overnight were used to help maintain MGA consumption.

To alleviate variation in MGA consumption, changes were made in nutritional management during the second year. Salt was restricted from all cattle 18 days before MGA feeding. Soybean hull pellets (2 lb/hd/day) were fed 13 days before MGA feeding to acclimate cattle to bunks. Three days before MGA feeding, soybean hull pellets containing salt (.13 lb/lb feed) were provided to all cows (2 lb/hd/day). Soybean hull pellets (2 lb/hd/day) containing salt and MGA (.25 mg/lb) were fed during the treatment period to females in the MGA and MGA+P_4 treatment groups, while females in the PG group continued to receive pellets (2 lb/day) consisting of only soybean hulls and salt. Restriction of salt intake was implemented to stimulate a salt consumption desire. Including salt in the feed just prior and during MGA feeding was expected to decrease consumption variation of MGA as well as maintain MGA consumption over the 18-day treatment period. From end of treatment until the end of estrous detection and AI, all females were fed

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pellets containing soybean hulls and salt. During 1995 and 1996, MGA failed to suppress ovulation during treatment in 20 of 132 (15.2%) and 13 of 118 (11%) of females treated with MGA or MGA+P_4. In 1996, body condition scores (1 = thin, 9 = fat) were assessed for all animals on day 0 and day 17 of the experiment.

Blood samples were collected on day 0 (initiation of MGA feeding), 7 and 17 of the experiment to characterize progesterone concentrations and determine estrual status (exhibiting estrous cycles or anestrus). Blood samples collected on day 0, 7, 9, 11, 13, 15 and 17 were used to determine concentration of estradiol in circulation.

Females with concentrations of progesterone ≥ 1 ng/ml of serum on day 0, 7 or 17 were considered to have luteal function and were categorized as estrual. All other females were categorized as anestrus.

Females were observed for behavioral estrus every 6 hours from day 17 (last day of MGA feeding or 2nd injection of $PGF_{2\alpha}$) until day 24 with the aid of K-Mar devices and epididymal ligated bulls. Females exhibiting signs of estrus were bred by AI 6 to 12 hours following detection. Uterine ultrasonography was performed 35 to 40 days following AI to determine conception rate.

Results and Discussion

Concentration of Estradiol

Concentration of estradiol was elevated during or increased near the end of treatment among both anestrous and estrual females treated with only MGA (Figures 1 through 4). Among estrual females, corpus luteum regression would have occurred at random during the treatment period. Treatment with MGA in the absence of a corpus luteum allows for increased pulse frequency of LH, resulting in development of persistent ovarian follicles and associated elevated concentrations of estradiol. Random initiation of development of persistent ovarian follicles corresponding with onset of luteal regression likely occurred in the present study. As indicated by the elevated concentration of estradiol in circulation on day 17 of the experiment, a majority of estrual females likely had persistent follicles present in their ovaries at cessation of MGA feeding.

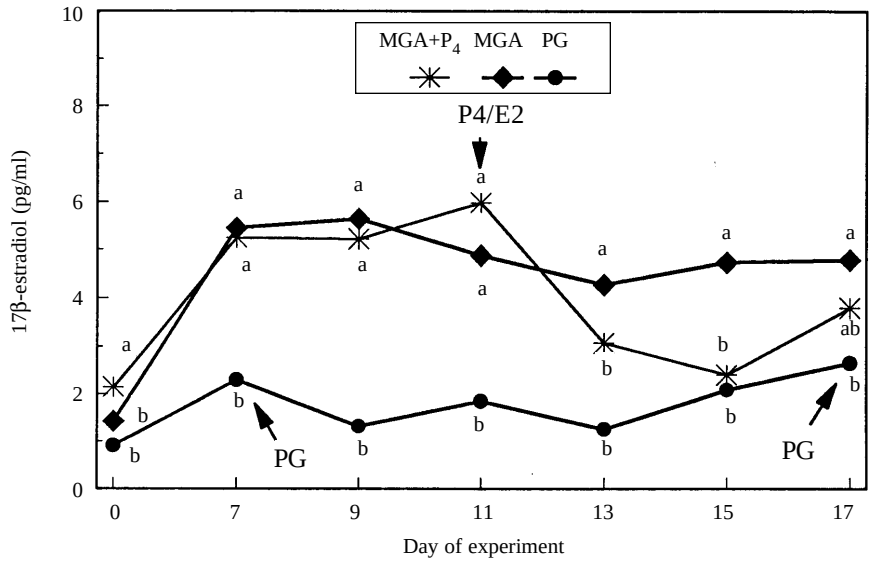

Figure 1. Concentration of estradiol among anestrous composite females during treatments to synchronize estrous cycles. Uncommon superscript letters within day indicate differences across treatment groups (^{a,b,c} P < .05).

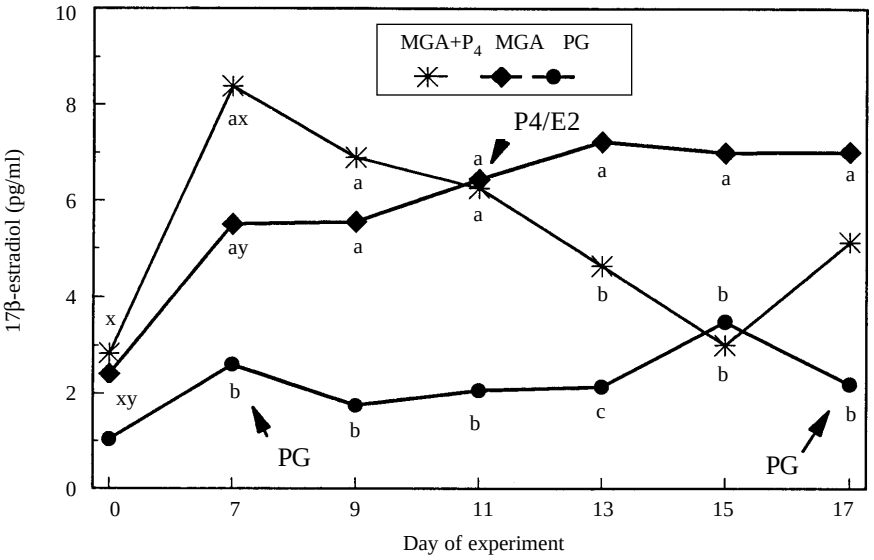

Figure 2. Concentration of estradiol among anestrous Angus x Gelbvieh females during treatments to synchronize estrous cycles. Uncommon superscript letters within day indicate differences across treatment groups (^{a,b,c} P < .05;^{x,y} P < .10).

Generally, concentrations of estradiol were greater during the treatment period among anestrous females fed MGA as compared with the PG group. This indicates treatment of anestrous females with a progestin such as MGA is able to elicit changes, presumably in secretion of LH, and subsequently in ovarian follicle development and secretion of estradiol.

Among anestrous females of both breeds and estrual composite females in the MGA+P_4 group, concentrations of estradiol decreased from day 11 to day 13. Administration of progesterone and estradiol in oil to females of this group occurred on day 11 and was expected to induce regression of persistent ovarian follicles. The sharp decline in concentration of estradiol among

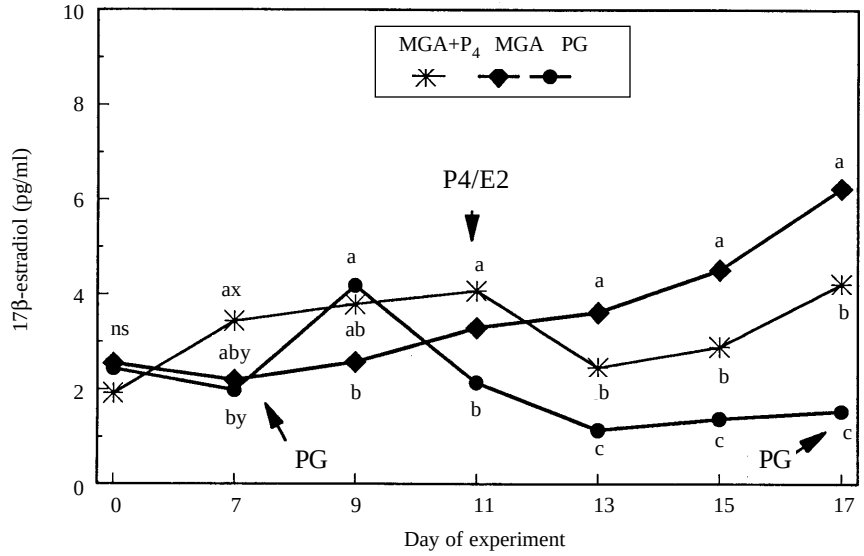

Figure 3. Concentration of estradiol among estrual composite females during treatments to synchronize estrous cycles. Uncommon superscript letters within day indicate differences across treatment groups (^{a,b,c} P < .05; ^{x,y} P < .10).

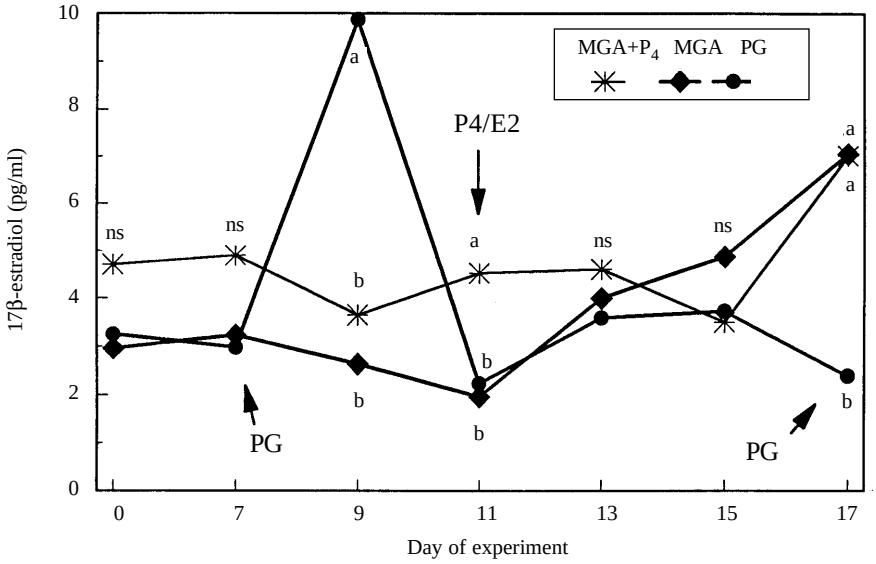

Figure 4. Concentration of estradiol among estrual Angus x Gelbvieh females during treatments to synchronize estrous cycles. Uncommon superscript letters within day indicate differences across treatment groups (^{a,b,c} P < .05).

anestrous and estrual females of composite breeding in the MGA+P_4 group indicates that regression of persistent ovarian follicles was achieved. It is unclear why estrual females of Angus x Gelbvieh breeding did not have a similar estradiol concentration decline following the injection of progesterone and estradiol. Perhaps a significant portion of these females were in the luteal phase of their estrous cycle at the time of the injection (on day 11) such that no persistent ovarian follicles were present to regress.

Concentration of estradiol increased on day 9 among estrual females in the PG group. The especially large increase in concentration of estradiol on day 9 among estrual Angus x Gelbvieh heifers was apparent among most females treated with $PGF_{2\alpha}$ on day 7. Corpus luteum regression, and initiation of the follicular phase of the estrous cycle, would have occurred among females treated with $PGF_{2\alpha}$ that had a corpus luteum capable of responding to $PGF_{2\alpha}$ on day 7. The increase in estradiol concentration on day 9 would coincide with development of the ovulatory follicle. Absence of an estradiol increase among anestrous females on day 9 confirms these females were anestrous during the treatment period.

Time to estrus

Treatment and estrual status interacted (P = .02) to affect time to estrus. Among anestrous females, interval from treatment cessation to onset of estrus was similar among females in the PG as compared with the MGA+P_4 group (Table 1). Compared to females treated with MGA, interval from treatment cessation to onset of estrus was shorter (P = .006) among females treated with MGA+P_4 and tended (P = .09) to be shorter among females treated with PG. Among estrual females, interval from treatment cessation to onset of estrus was similar among females in the MGA and MGA+P_4 groups and MGA and PG groups, but was shorter (P = .05) in females treated with PG as compared with those treated with MGA+P_4.

We expected treatment with MGA alone would result in the shortest interval to estrus onset due to the advanced stage of ovarian follicle development at the time of treatment withdrawal. Perhaps ovarian follicles of some animals were not at an advanced stage of development at treatment withdrawal, but rather had undergone natural atresia before cessation of MGA feeding.

Estrous synchrony rate

Treatment and estrual status interacted (P < .001) to affect estrous synchrony rate (number in estrus/number in group; Table 1). Among anestrus females, a greater (P < .001) percentage of females in the MGA and MGA+P_4 groups exhibited estrus following treatment compared with females in the PG group. There tended to be a greater (P = .10) percentage of anestrous females in the MGA+P_4 group exhibiting estrus following treatment compared with the MGA group. Among estrual females, a greater percentage of females in the PG

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Table 1. Estrous synchrony rates, conception and pregnancy rates to AI and time to behavioral estrus of females treated with MGA, MGA+P_4, or PG.

	Treatment		
Item	MGA	MGA+P_4	PG
Time to estrus, hours ± SEM[a]			
Anestrus	98.8 ± 5.5[x]	76.7 ± 5.7[y]	76.0 ±12.4[y]
Estrual	75.7 ± 6.2[xy]	79.8 ± 4.4[x]	66.7 ± 5.2[y]
Estrous synchrony rate, %[a]			
Anestrus[c]	66.1[x]	81.4[y]	28.0[z]
Estrual[d]	76.6[x]	89.9[y]	92.3[y]
Conception rate, %	50.0[x]	62.7[xy]	67.4[y]
Pregnancy rate, %[b]			
Anestrus	33.9[x]	45.8[x]	16.0[y]
Estrual, 1995	44.2[x]	51.2[xy]	64.7[y]
Estrual, 1996	23.8[x]	76.9[y]	63.0[y]

[a]There was a treatment x estrual status interaction ($P < .001$), therefore animals that were estrual and anestrus were analyzed separately.
[b]There was a treatment x estrual status interaction ($P = .003$), therefore animals that were estrual and anestrus were analyzed separately. Within estrual animals there was a treatment x year interaction (P = .06), therefore estrual animals within each year (1995 and 1996) were analyzed separately.
[x, y, z]Means within a row lacking a common superscript differ ($P \leq .10$).

($P = .02$) and MGA+P_4 ($P = .07$) groups exhibited estrus following treatment compared with the MGA group; however, estrous synchrony rates were similar among females in the PG and MGA+P_4 groups. Body condition score, age, number of days postpartum and year neither affected nor interacted with treatment to alter estrous synchrony rate.

Estrous synchronization rates are typically improved with progestin-based estrous synchrony programs because of the progestin's ability to induce estrous cycles in anestrous females. In this study, 23% of heifers and 48% of cows were determined to be anestrus prior to end of treatment. A greater percentage of anestrous females in the MGA (66%) and MGA+P_4 (81%) groups were induced to exhibit estrus following treatment compared with the PG group (28%). Among both anestrous and estrual females, a greater percentage of females in the MGA+P_4 group exhibited estrus following treatment compared with MGA treatment alone. It is unclear why additional treatment with progesterone and estradiol improved estrous synchrony rate.

Inconsistent consumption of MGA, especially during 1995, likely resulted in lower estrous synchronization rates among females in the MGA+P_4 and MGA groups. During 1995 and 1996, 15 and 11 %, respectively, of females fed MGA appeared to have ovulated during MGA feeding. During 1996, we attempted to alleviate problems regarding consumption of MGA by strategic restriction and replacement of salt in the rations. This change resulted in a 4 % decrease in females ovulating during MGA feeding. Females in this study were maintained on pasture during the experiment and MGA feeding occurred in May, a time of maximal forage growth in both 1995 and 1996. As a result, cattle were more likely to graze and become satiated on forages, decreasing consumption of MGA. It is likely that in a drylot situation, estrous synchronization of beef females with MGA plus progesterone and estradiol would result in an improved estrous synchronization rate.

Conception rate

Conception rate (number conceived to AI/number AI'ed) did not differ among females in either the PG or MGA+P_4 groups, but was greater (P =.04) among females in the PG as compared with MGA group (Table 1).

Conception rate to AI was acceptable among females in the PG and MGA+P4 groups. Conception rate of females treated with MGA alone was greater than expected. Treatment with doses of commercially used progestins or low doses of progesterone in the absence of a corpus luteum results in development of persistent ovarian follicles. Perhaps during the long-term MGA feeding, some persistent ovarian follicles naturally regressed, allowing AI to coincide with ovulation of typically developing ovulatory follicles, improving conception rates. The elevated concentrations of estradiol among both anestrous and estrual composite and Angus x Gelbvieh females indicate large, persistent ovarian follicles were still present near the end of the treatment period.

Pregnancy rate

Treatment and estrual status interacted (P =.003) to affect pregnancy rate (number conceived to AI/number in group; Table 1). There was an effect ($P < .05$) of year on pregnancy rate among anestrous females where pregnancy rate did not differ among females in the MGA or MGA+P_4 groups, however, it was greater among females in the MGA ($P = .05$) and MGA+P_4 ($P < .01$) groups as compared with the PG group.

Among estrual females, treatment and year interacted (P =.06) to affect pregnancy rate. Among estrual females in 1995, pregnancy rate was greater ($P = .05$) among females treated with PG as compared with MGA, but did not differ from females treated with MGA+P_4. Among estrual females in 1996, pregnancy rate was greater ($P \leq .01$) among females treated with MGA+P_4 or PG as compared with MGA, but did not differ among females treated with MGA+P_4 and those treated with PG.

Pregnancy rates to AI among anestrous females were greater among females in the MGA or MGA+P_4 groups as compared with the PG group. Clearly, this advantage in pregnancy rate is due primarily to the improved rate of estrous synchrony achieved following treatment with MGA versus $PGF_{2\alpha}$. During 1996, consistent consumption of MGA was improved as compared to 1995. This is evidenced by more females consuming pellets for longer periods of time following feeding, but does not readily explain the 20 % decrease in pregnancy rate from 1995 to 1996 in estrual females in the MGA group as compared with the 25% in-

crease in pregnancy rate of estrual females in the MGA+P_4 group. It is important to recognize estrous synchronization of anestrous females with MGA plus progesterone and estradiol results in greater pregnancy rates as compared with PG, whereas among estrual females, greater pregnancy rates can be achieved following estrous synchronization with MGA plus progesterone and estradiol as compared with MGA alone. Ultimately, cow/calf producers are interested in maximizing herd pregnancy rates. Because most beef herds would likely consist of anestrous and estrual females, pregnancy rates to AI would be maximized most effectively by estrous synchronization with MGA plus progesterone and estradiol.

For beef producers to achieve maximal pregnancy rates, estrous synchronization rates, as well as conception rates, must be maximized. The present study provides evidence that long-term feeding of MGA, combined with an injection of progesterone and estradiol, is effective in synchronizing estrus and achieving acceptable conception rates to AI among both anestrous and estrual beef females.

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[1]Karol Fike, former graduate student. Michael Wehrman, former graduate student. Brad Lindsey, graduate student. Ellen Bergfeld, former graduate student. Eric Melvin, former graduate student. Jorge Quintal, former graduate student. Eraldo Zanella, graduate student. Freddie Kojima, former graduate student. James Kinder, Professor, Animal Science, Lincoln.

Effects of Luteinizing Hormone Releasing Hormone Antagonist On The Bovine Corpus Luteum

Deb Clopton
Jorge Quintal
Freddie Kojima
Karol Fike
Jim Kinder[1]

Pulsatile luteinizing hormone release during the follicular phase of the estrous cycle affects size and function of the corpus luteum and is important in achieving optimal cattle pregnancy rates.

Summary

The size and function of the corpus luteum were examined after administration of luteinizing hormone releasing hormone antagonist. Luteinizing hormone releasing hormone antagonist was administered to three animal groups starting: 1) 2 days before the preovulatory luteinizing hormone surge inducing ovulation; 2) at initiation of the preovulatory surge; and 3) 2 days after the preovulatory surge. Although size and function of the corpus luteum were suppressed in all treated groups, the greatest developmental suppression occurred when luteinizing hormone release was blocked 2 days before the preovulatory surge of LH inducing ovulation. Therefore, optimal pregnancy rates in cattle may depend on pulsatile release of LH during the follicular phase of the estrous cycle in addition to that secreted during and after ovulation.

Introduction

The corpus luteum (CL) develops from an ovarian follicle following ovulation and secretes the progesterone required to support pregnancy. It has been widely observed that luteinizing hormone (LH) is essential for the maintenance of progesterone production by bovine luteal cells and recently shown that LH pulse frequency is greater during the follicular phase than the midluteal phase of the estrous cycle. It has also been shown LH secretion is not required to maintain luteal function during the late luteal phase of a cow's estrous cycle.

It is apparent the CL requires a specific endocrine environment and deviations from this can be detrimental for normal development of structure and function of luteal tissue. Presently, information is scarce concerning the role of LH secretion on luteal development and function during the follicular phase and the periovulatory stages of the reproductive cycle. Treatment with luteinizing hormone releasing hormone (LHRH) antagonist to inhibit LH pulses enables the role of LH pulses before, during and after the preovulatory surge of LH on CL development and function to be assessed.

Procedure

Experimental Protocol

This study used 21 postpubertal heifers of composite breeding (1/4 Hereford, 1/4 Angus, 1/4 Redpoll, 1/4 Pinzgauer; 972 lbs). Estrous synchrony was achieved with two injections of prostaglandin $F_{2\alpha}$ ($PGF_{2\alpha}$) administered 11 days apart. Heifers were randomly assigned to one of the following treatments: 1) 5% mannitol injections serving as a control; 2) LHRH-Antagonist (LHRH-Ant) starting 2 days before initiation of the preovulatory LH surge; 3) LHRH-Ant at initiation of the preovulatory LH surge; and 4) LHRH-Ant starting two days after the preovulatory LH surge. LHRH-Ant is a synthetic peptide which selectively blocks LH secretion. It was administered subcutaneously to all treated groups every 24 hours at 10µg/kg body weight until day 7 of the estrous cycle. Preovulatory surges of LH were experimentally

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induced in all heifers by intravenous administration of purified bovine LH (preovulatory LH surge = day 0) every 20 minutes for 3 hours beginning 48 hours after the second injection of $PGF_{2\alpha}$ in order achieve an initial concentration of 100 ng/mL and to maintain a concentration of 50 ng/ml. All follicles larger than 5 mm were ablated by transvaginal procedures four days prior to the second treatment of $PGF_{2\alpha}$ utilizing an ultrasonography probe equipped with a needle guide attachment. This ensured synchrony of the waves of ovarian follicular development and that dominant follicles were at the same developmental stage at corpus luteum regression.

Measurements and Sample Collection

Ovulation and development of the CL (size in mm) were monitored by ultrasonography daily until day 12 of the estrous cycle and every other day until day 28. Ovulation was identified as the disappearance of a large ovarian follicle between two consecutive days of ultrasonography. Starting at the time of the second treatment of PGF_{2a} plasma was obtained from blood samples collected every 12 hours until day 28 or the time of subsequent behavioral estrus detection, whichever occurred first. Concentrations of progesterone in plasma were analyzed by radioimmunoassay (RIA). To verify accuracy of exogenous LH treatment, serum was obtained from blood samples collected every 20 minutes starting 2 hours before the first LH treatment and ending 2 hours after the last injection. Serum concentrations of LH were analyzed by RIA.

Results

Size of Corpus Luteum

Size of the CL was largest (P<.01) in control group heifers and smallest in heifers in which LH release was blocked starting 2 days before the preovulatory surge of LH (Figure 1). Size of the CL in heifers in which LH release was blocked, starting coincident with or 2 days after the preovulatory surge of LH, was less than controls but greater

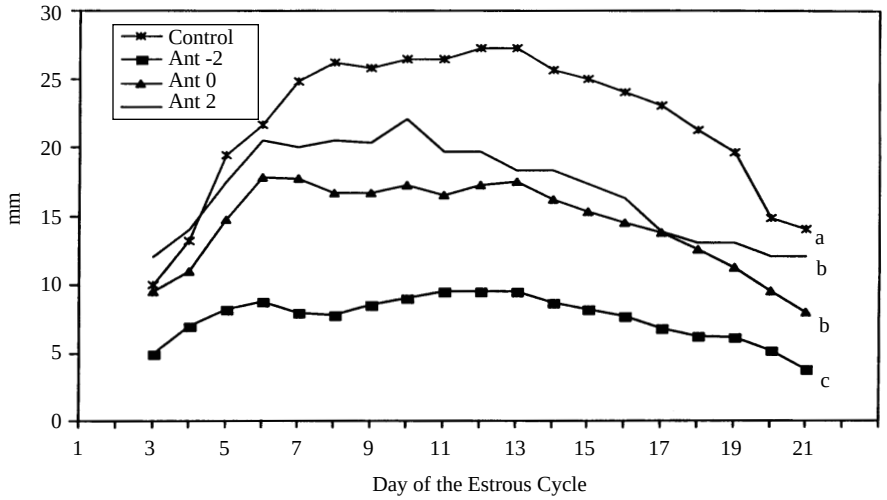

Figure 1. Size of the corpus luteum in heifers treated with LHRH antagonist at different times relative to the preovulatory surge of LH and untreated controls (a,b,c=p<0.01).

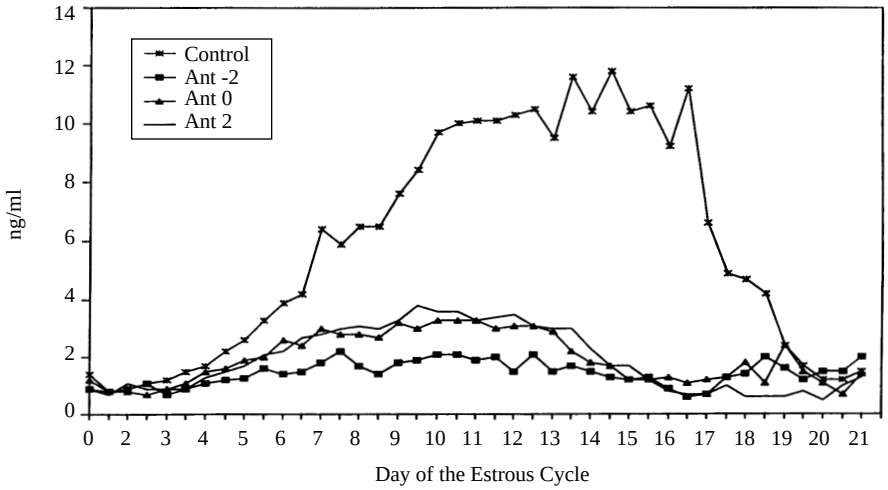

Figure 2. Mean concentrations of progesterone in plasma from heifers treated with LHRH-antagonist at different times relative to the preovulatory surge of LH and untreated controls. Control group is different from treated groups (P<0.01).

(P<.01) than in heifers in which LH suppression started 2 days before the preovulatory surge of LH. There was no difference (P>.1) in size of the CL among heifers in which LH suppression started coincident with the preovulatory surge of LH or 2 days after the preovulatory surge of LH. Average size of CL was 9.5, 17.5, 21.6 and 28.8 mm (pooled SE = 0.43) for heifers in which LH secretion was blocked starting 48 hours before, at time of initiation or 48 hours after the preovulatory surge of LH and control heifers, respectively.

Progesterone Concentrations

Compared with secretion of progesterone (area under the curve) from the control group, secretion of progesterone was less (P<.01) in heifers where LH release was suppressed prior to, during or after the LH surge (Figure 2). Arbitrary units under the progesterone release curve for heifers in which LH secretion was blocked starting 48 hours before, at the time of initiation or 48 hours after the preovulatory surge of LH and the control group were 19.6, 41.6, 43.6 and 142.2, respectively. There was no difference in function of the CL (P>.1) as determined by arbitrary units of progesterone of heifers in the three groups in which LH secretion was blocked.

Conclusions

Results from this study indicate LH pulses subsequent to the preovulatory LH surge are necessary for development of a CL with similar size and functionality as those observed in control heifers. The influence of LH secretion during late ovarian follicular maturation and early luteal development appear to be additive in developing CL of typical structural size. LH appears to have a differential effect on development and function of the CL in cattle. The effects of LH on luteal function, as evaluated by circulating concentrations of progesterone, appear to be more dramatic than the influence of LH pulses on development of a CL of typical structural size.

Inadequate numbers of LH receptors on both granulosa and thecal cells, due to the absence of LH pulses prior to the preovulatory surge, may account for the smaller luteal structure in which release of LH was blocked 48 hours before the LH surge. Alternatively, the smaller CL in these heifers may be the result of altered populations of luteal cells. Small luteal cells possess functional LH receptors. Large luteal cells do not possess functional LH receptors; however, they will secrete large amounts of progesterone in the absence of LH stimulation. Therefore, it is possible that, in the absence of pulsatile LH secretion during the late stages of ovarian follicular maturation and early luteal development, small luteal cells do not receive the proper stimulus to secrete progesterone and without LH support are not able to develop into large luteal cells that will secrete larger amounts of progesterone. Thecal, granulosal and luteal cells require pulsatile LH support during the periovulatory stages of the estrous cycle for development of a luteal structure with typical size and steroidogenic capacity in cattle.

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[1]Deb Clopton, research technician; Jorge Quintal, Freddie Kojima, and Karol Fike, former graduate students; Jim Kinder, professor, Animal Science, Lincoln.

Regulation of LH Secretion by Progesterone in Heifers

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Release of LH is regulated more by circulating amount of progesterone than by the magnitude of shift in progesterone. Understanding interactions of reproductive hormones advances development of management tools for producers to control estrous cycles of beef females.

Summary

Heifers experienced either a: 1) large magnitude of change in progesterone; 2) medium magnitude of change in progesterone; or 3) small magnitude of change in progesterone. During the 24 hours following the progesterone shift, heifers with the large magnitude progesterone shift had a greater LH pulse frequency than heifers with a medium or small magnitude of shift in progesterone. Despite the large or medium magnitude progesterone shift, LH pulse frequency did not differ from heifers in which a small change in progesterone occurred. We conclude that amount of progesterone in circulation is more important in regulation of LH secretion than magnitude of shift in amount of progesterone.

Introduction

Secretion of LH is an important component of cattle reproduction because it is necessary for the development of ovarian follicles, estradiol production, ovulation and the formation of corpora lutea. Pattern of LH secretion changes during the estrous cycle of cattle and is influenced by concentration of progesterone and estradiol.

Regulation of LH secretion by progesterone is relatively acute, as within 6 hours following a shift from a small to large dose of progesterone, a significant change in pulse frequency of LH was observed. Understanding the endocrine mechanisms by which reproductive hormones, such as progesterone and LH, interact will enhance development of new management techniques to control estrous cycles of beef cattle.

The objective of this study was to determine whether magnitude of shift in progesterone or circulating amount of progesterone is more important in regulating LH secretion during the 72 hours after the progesterone shift.

Materials and Methods

Seventeen post-pubertal beef heifers (MARC III; 1/4 Hereford, 1/4 Angus, 1/4 Pinzgauer and 1/4 Red Poll) were synchronized to a common day of estrus with two i.m. injections of

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$PGF_{2\alpha}$ (25 mg Lutalyse®; The Upjohn Co., Kalamazoo, MI) given 10 days apart. During the eighth day of their estrous cycle, heifers were injected with a single dose of $PGF_{2\alpha}$ to regress existing corpora lutea and treatments were initiated (day 0). From day 0 to day 4, heifers were treated with various doses of progesterone via progesterone-releasing intravaginal devices (.5 to 2 PRIDs; Sanofi Animal Health Inc., Paris, France) followed by a large dose of progesterone (2 PRIDs) from day 4.5 to day 7. Change in dose of progesterone occurred on the morning of day 4, within 4 hours following collection of the day's blood sample. At this time, PRIDs were removed from each heifer followed by immediate insertion of 2 PRIDs.

Based on mean magnitude of concentration change of progesterone in circulation from day 0 to day 4 relative to day 4.5 to day 7, heifers were placed into one of the following groups: 1) large magnitude of change in concentration of progesterone (3.1 ng/ml; n=6); 2) medium magnitude of change in concentration of progesterone (2.5 ng/ml; n=6); or 3) small change in concentration of progesterone (0.5 ng/ml; n=5).

Blood Collection and Radioimmunoassays

Jugular blood samples were collected every 12 hours from day 0 to day 7 and used to assess circulating concentrations of estradiol and progesterone. Jugular blood samples were also collected via cannulae every 15 minutes from day 3.5 to day 7 to assess concentrations of LH in circulation.

Table 1. Mean concentration of LH, LH pulse frequency and amplitude, and mean magnitude of change in amount of progesterone of heifers with a large, medium, or small magnitude of shift in amount of progesterone.

Item		Group		
		LG	MD	SM
Mean magnitude of change in progesterone (ng/ml)[a]		3.1[b]	2.5[c]	0.5[d]
Mean LH (ng/ml):	Pre-shift -12 to 0 hours	2.1[b]	1.7[c]	1.2[d]
	Post-shift 0 to 24 hours	1.2[b]	1.2[b]	1.0[b]
	Post-shift 24 to 48 hours	1.1[b]	1.1[b]	1.1[b]
	Post-shift 48 to 72 hours	1.2[b]	1.4[b]	1.4[b]
LH pulses/12 h:	Pre-shift -12 to 0 hours	9.7[b]	6.5[c]	3.4[d]
	Post-shift 0 to 24 hours	5.4[bx]	2.8[c]	2.9[bcy]
	Post-shift 24 to 48 hours	3.3[b]	2.9[b]	3.5[b]
	Post-shift 48 to 72 hours	4.3[b]	4.8[b]	5.3[b]
LH pulse amplitude (ng/ml):	Pre -shift -12 to 0 hours	1.4[b]	1.4[b]	1.5[b]
	Post-shift 0 to 24 hours	0.8[b]	0.9[b]	0.8[b]
	Post-shift 24 to 48 hours	0.6[b]	0.5[b]	1.7[c]
	Post-shift 48 to 72 hours	0.9[bx]	1.5[bcy]	1.6c

[a]Mean change in concentration of progesterone from day 0 to 4 relative to day 4.5 to 7 of the experiment.
[b,c,d]Means within a row without common superscripts differ P≤ .05.
[x,y]Means within a row without common superscripts differ P < .10.

Results

Progesterone, secreted by a corpus luteum, regulated the estrous cycle in cattle such that in the presence of increased concentrations of progesterone, pulse frequency of LH is low and estrus and ovulation are inhibited. Treatment of beef females with doses of commercially used progestins (norgestomet, melengestrol acetate or progesterone) in the absence of a corpus luteum is sufficient to inhibit ovulation. However, it does not regulate pulse frequency of LH like the greater concentrations of progesterone present in circulation during the luteal phase of an estrous cycle. Consequently, LH pulses are more frequent during treatment with small doses of progestins than during the luteal phase of an estrous cycle. Pulse frequency changes affect ovarian follicle development and their secretion of estradiol (see "Prolonged Elevated Concentration of Estradiol Do Not Affect Conception Rates in Beef Cattle" in this NE Beef Report).

Researchers have hypothesized that magnitude of change in progesterone concentration (or dose of progestin) is involved, along with amount of progesterone, in regulation of pulse frequency of LH. This hypothesis was suggested because an evaluation of LH pulse pattern of individual animals from a previous study in our laboratory indicated a possible relationship between magnitude of shift in progesterone dose and duration of cessation of pulsatile LH secretion.

In this study, mean magnitude of change in progesterone concentration from day 0 to day 4 relative to day 4.5 to day 7 differed across groups ($P < .02$; Table 1). There were group x day interactions for mean concentrations of progesterone ($P < .001$; Figure 1) and estradiol ($P < .01$) during treatment (day 0 to day 7). Pulse frequency and mean concentration of LH differed ($P < .05$) across groups during the 12 hours before the shift in progesterone (Table 1). Pulse frequency of LH was greater ($P = .05$) among heifers with the large magnitude of change in concentration of progesterone as compared with the medium during the first 24 hours following the shift in progesterone concentration. Pulse frequency of LH tended to be greater ($P < .10$) during the first 24 hours following the shift in progesterone concentration among heifers with the large magnitude of change as compared with the small magnitude of change. From 24 to 48 hours and 48 to 72 hours following the shift in progesterone concentration, pulse frequency of LH was similar across groups. Mean concentration of LH was similar across groups during the first 24 hours and from 24 to 48 hours and 48 to 72 hours following the shift in progesterone.

Before the shift in dose of progesterone, there was an inverse relationship

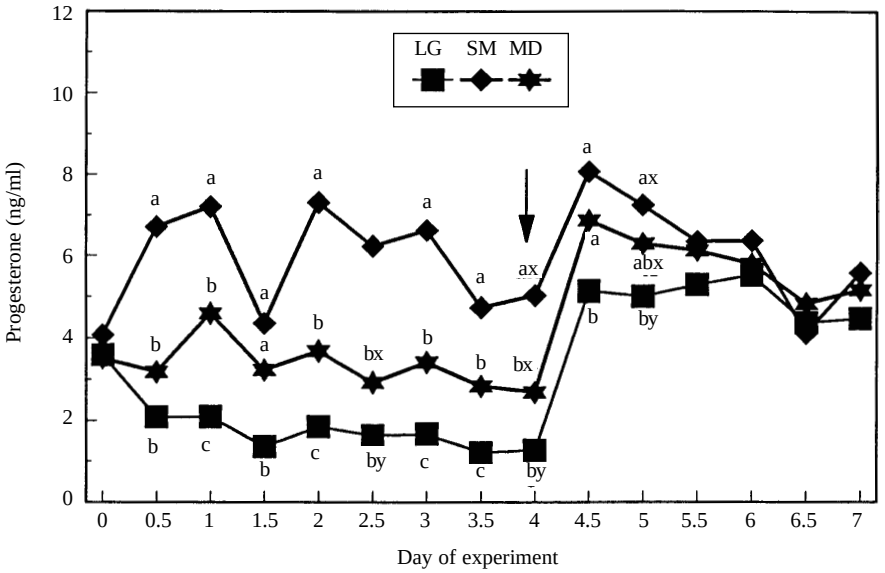

Figure 1. Concentrations of progesterone in circulation of heifers with a large (LG), medium (MD) or small (SM) magnitude of change in concentration of progesterone. Arrow indicates time of shift from various doses to a relatively large dose of progesterone. There was a group x day interaction (P < .01). Differences in progesterone across groups within day are indicated by uncommon superscript letters (^{a,b}P < .05; ^{x,y} P< .10).

between circulating concentration of progesterone and estradiol (data not shown). Heifers with lesser circulating concentration of progesterone and increased pulse frequency of LH (Table 1) likely developed large dominant ovarian follicles, resulting in the increased concentrations of circulating estradiol. Additionally, circulating concentrations of progesterone differed across groups (Figure 1) before the shift in progesterone. Differences in frequency of LH pulses, before the shift in progesterone amount, can likely be attributed to differences in amount of both progesterone and estradiol. Previous research has shown that when both progesterone and estradiol are present in circulation, a greater suppression of LH pulse frequency is achieved than with either steroid alone. Following the progesterone shift, however, concentration of estradiol was similar among the three groups of heifers. Therefore, differences in frequency of LH pulses following the shift may be attributed solely to progesterone and not estradiol.

Heifers experiencing a large magnitude of change in progesterone concentration had less circulating progesterone and, subsequently, greater pulse frequency of LH during the first 24 hours following the shift in progesterone concentration. Apparently, the large magnitude of shift in progesterone concentration in these heifers did not affect pulse frequency of LH, but rather frequency of LH pulses during the first 72 hours following the progesterone shift was regulated by amount of progesterone in circulation and not the magnitude of the shift. Heifers with either medium or small magnitudes of shift in progesterone had similar concentrations of progesterone in circulation following the shift. Subsequently, frequency of LH pulses was similar among heifers of all three groups following the progesterone shift irregardless of the magnitude of the shift. Based on these results, it appears that amount of progesterone, rather than magnitude of shift, is more important in regulation of pulsatile secretion of LH during the 72 hours after the shift in progesterone. An acute shift in amount of progesterone, however, appears to regulate pulsatile secretion of LH to some extent as an acute shift in amount in circulation dramatically affects secretion of LH. This contrasts the gradual changes observed in release of LH during a typical estrous cycle, when changes in progesterone concentration also are relatively subtle and gradual.

Pulse amplitude of LH was similar across groups during the 12 hours before and the first 24 hours following the shift in progesterone (Table 1). From 24 to 48 hours following the shift in progesterone concentration, pulse amplitude of LH was greater (P < .01) among heifers experiencing a small magnitude of change in progesterone as compared with heifers experiencing a large or medium magnitude of change in progesterone. From 48 to 72 hours following the shift, pulse amplitude of LH was greater (P < .05) among heifers with a small magnitude of change in progesterone concentration and tended (P < .10) to be greater among heifers with a medium magnitude of change in progesterone as compared with heifers that had a large magnitude of change in progesterone. These differences in LH pulse amplitude appear to reflect sequential adjustments to the three magnitudes of shift in progesterone. Greater amplitudes of LH pulses resumed earlier following the shift among heifers with the small, followed by the medium and lastly the large magnitude of shift in progesterone.

Results from this study indicate LH pulse frequency appears to be influenced more by amount of progesterone in circulation than by magnitude of shift in progesterone. The LH pulse generator does not appear to be sensitive to different magnitudes of change in amount of progesterone.

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Prolonged Elevated Concentrations of Estradiol Do Not Affect Conception Rates in Beef Cattle

Karol Fike
Michael Wehrman
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James Kinder[1]

Persistent ovarian follicles and associated elevated concentrations of estradiol which develop during progestin-based estrous synchrony programs are not detrimental to fertility if persistent ovarian follicles are not allowed to ovulate.

Summary

Following treatments causing either prolonged elevated concentrations of estradiol associated with development of persistent follicles or inhibited elevated concentrations of estradiol and development of persistent follicles, conception rates were compared. Beef females received either four norgestomet implants for 9 days (day 0 = treatment initiation; n=59) or one norgestomet implant for 7 days and three additional norgestomet implants for 2 days (n=60). All implants were removed on day 9 followed by estrous detection and AI for 7 days. Treatment and day interacted to affect estradiol concentrations from day 0 to day 9 with elevated estradiol in females treated with one norgestomet implant for 7 days. Conception rates to AI were similar across treatments. Prolonged elevated concentrations of estradiol associated with development of persistent ovarian follicles do not affect fertility when persistent ovarian follicles are not allowed to ovulate.

Introduction

Cattle treated with commercial doses of synthetic progestins, such as melengestrol acetate and norgestomet or small doses of progesterone in the absence of corpora lutea, often develop persistent ovarian follicles. These follicles develop because of greater LH pulse frequency than naturally occurs during the luteal phase which, in turn, promotes prolonged development of the dominant follicle and increased concentrations of estradiol.

Reduced fertility is associated with estrus and mating following development and ovulation of persistent ovarian follicles. This fertility reduction may be due to adverse effects of prolonged elevation of estradiol on the reproductive tract, compromised oocyte development in persistent ovarian follicles or a combination of these factors.

The objectives of this study were to compare conception rates and time to estrus in cattle following treatments designed to: 1) inhibit persistent ovarian follicle development and elevated concentrations of estradiol; or 2) cause development of persistent ovarian follicles and prolonged elevated concentrations of estradiol, but inhibit ovulation of the follicles.

Procedure

Heifers (n=80) and 2-year-old MARC III (1/4 Angus, 1/4 Red Poll, 1/4 Pinzgauer, 1/4 Hereford) cows (n=39) from the beef physiology herd were injected twice with $PGF_{2\alpha}$ (25 mg; Lutalyse® Sterile Solution, Upjohn, Kalamazoo, MI) 11 days apart. The last injection occurred on the day of treatment initiation to destroy the function of existing corpora lutea and synchronize the estrous cycle stage prior to experiment. All females exhibiting estrus were 6 to 8 days post-estrus at treatment initiation. Females were stratified by age, blocked by estrual status (previously exhibited estrus or anestrus) and assigned to receive either: 1) four norgestomet implants (4 Norg; n=59; hydron implant with 6 mg norgestomet; Sanofi Animal Health Inc., Overland Park, KS) for 9 days (day 0 = treatment initiation); or 2) one norgestomet implant from day 0 to day 7 and three additional norgestomet implants from day 7 to day 9 (1+3 Norg; n=60). All females received an injection of $PGF_{2\alpha}$ (25 mg) at treatment initiation and all implants were removed on day 9. Females were observed for signs of behavioral estrus every 6 hours from time of implant removal (day 9) until day 16 with the aid of K-Mar devices and epididymal ligated bulls. Females exhibiting estrus were bred by AI 6 to 12 hours following estrus detection.

Blood samples were collected daily from treatment initiation (day 0) until the end of estrous detection and AI (day 16) and twice weekly for an additional 30 days thereafter. While concentrations of progesterone were determined in all samples collected, concentrations of estradiol were determined only in samples collected from day 0 to day 16.

Females were considered pregnant when, following breeding, concentrations of progesterone increased to above 2 ng/ml of serum and remained at concentrations characteristic of normal luteal function until termination of the experiment. Uterine ultrasonography

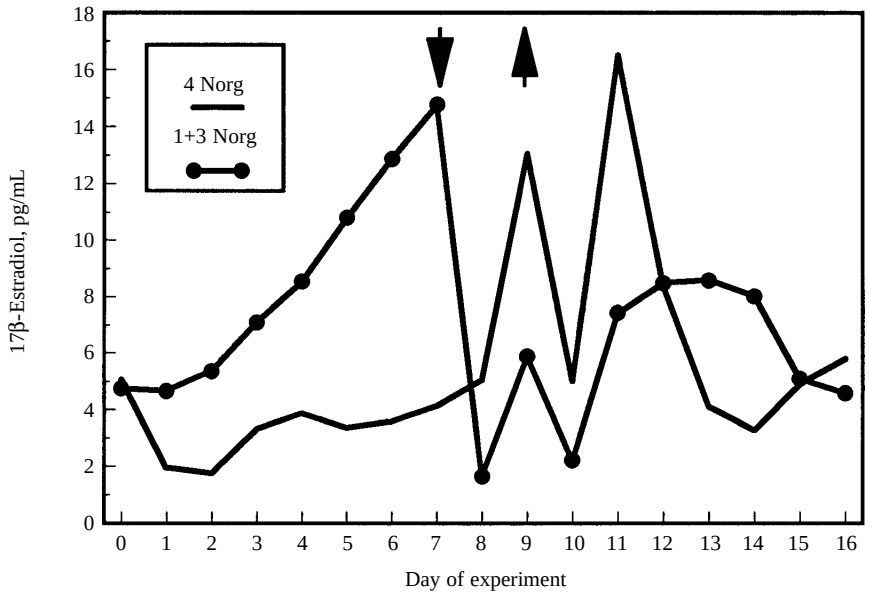

Figure 1. Concentrations of estradiol in circulation from day 0 to 16 of the experiment of females during treatment with either four norgestomet implants for 9 days (4 Norg) or one norgestomet for 7 days followed by an additional three implants for 2 days (1+3 Norg). Arrows indicate day of insertion of 3 norgestomet implants in 1+3 Norg treatment group and day of removal of all implants for both treatment groups. There is a treatment x day interaction ($P < .01$) from day 0 to 9 of the experiment.

approximately 35 days following AI was to confirm the progesterone profiles to determine if pregnancy occurred as a result of AI.

Results

There was a treatment x day interaction ($P < .01$) for concentrations of estradiol from day 0 to day 9 of the experiment, with elevated estradiol occurring in females receiving the 1+3 Norg treatment (Figure 1). The increase in concentration of estradiol from day 0 to day 7 in females treated with 1+3 Norg was indicative of persistent ovarian follicle development and the acute decline in estradiol observed after treatment with three additional norgestomet implants was indicative of induced atresia of persistent follicles. Concentration of progesterone in females of both treatment groups declined from day 0 to day 1 in response to $PGF_{2\alpha}$ injected on day 0 and remained low through day 9 of the experiment.

Estrous synchronization rate (number in estrus/number in treatment group) and pregnancy rate (number conceived to AI/number in treatment group) were affected ($P < .10$) by treatment x estrual status. Estrous synchronization rate of estrual females did not differ between treatment groups (Table 1). There was a greater percentage ($P < .10$) of previously anestrus females displaying signs of estrus within 7 days after removal of norgestomet implants in the 4 Norg group (97 %) as compared with the 1+3 Norg group (67 %). Age, estrual status, treatment x age and treatment x estrual status affected neither conception rates nor time to onset of behavioral estrus after removal of norgestomet implants. Conception rates (number conceived/number inseminated) to AI were not different among females treated with 1+3 Norg (72%) and those treated with 4 Norg (67%). Pregnancy rates of both estrual and anestrous females did not differ between treatment groups (Table 1). Mean time from norgestomet withdrawal to behavioral estrus was longer ($P < .001$) in females treated with 1+3 Norg (105 hours) than with females treated with 4 Norg (61 hours).

Table 1. Estrous synchrony rates, conception and pregnancy rates to AI and time to behavioral estrus of females treated with 1+3 Norg or 4 Norg implants

	Treatment	
	4 Norg	1+3 Norg
Estrous synchrony[a] (%)		
Estrual	97	100
Anestrous	97†	67
Conception Rate (%)	67	72
Pregnancy Rate[a] (%)		
Estrual	66	77
Anestrous	63	43
Time to estrus (hours)	61***	105

†P < .10
***P < .001
[a]There was a treatment x estrual status interaction ($P < .10$), therefore animals that were estrual and anestrous were analyzed separately.

Using two different protocols of synthetic progestin treatment, elevated concentrations of estradiol associated with development of persistent ovarian follicles were unable to affect conception rate to AI. Results indicate similar conception rates can be achieved in cattle in which progestin treatment allows a persistent ovarian follicle to develop and subsequently causes its regression, as compared with cattle in which larger doses of synthetic progestin treatment prohibit the development of persistent ovarian follicles. It appears that allowing persistent ovarian follicles and their associated elevated concentrations of estradiol to develop is not detrimental to fertility when the follicle is regressed before the ovulatory follicle associated with pregnancy ovulates. Conclusions drawn from this and other studies indicate decreased pregnancy rates observed in association with ovulation of a persistent ovarian follicle are likely due to abnormal maturation of the oocyte rather than effects of elevated concentrations of estradiol on oviductal or uterine function.

Because we induced regression of the persistent ovarian follicles by treatment with three additional norgestomet implants, we also shortened the duration of elevated concentrations of estradiol when compared with the duration in cattle ovulating persistent ovarian follicles. In cattle receiving the 1+3 Norg treatment, there was a 105 hour interval from time of removal of norgestomet implants until the onset of estrus; cows treated with 4 norgestomet implants had a 61 hour interval. It is possible lesser concentrations of

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circulating estradiol from the time of induced regression of the persistent ovarian follicle until preovulatory follicle development allowed for oviductal and uterine function to return to normal before the oocyte/embryo entered the reproductive tract. The extended interval from treatment withdrawal to onset of estrus may be due to an acute reduction in LH pulse frequency resulting from treatment with three norgestomet implants. It is likely treatment with the three additional norgestomet implants caused an immediate decrease in the frequency of LH pulses, induced atresia of the persistent ovarian follicle and delayed development of the next dominant follicle. Dominant persistent ovarian follicles suppress development of subordinate follicles; therefore, it is plausible that, in females treated with 1+3 Norg, subordinate follicles were smaller resulting from the presence of persistent ovarian follicles and thus required more time to develop to ovulation.

The present study provides evidence that estrous synchrony programs based on treatment with doses of commercially used synthetic progestins will not result in compromised fertility at the synchronized estrus if persistent ovarian follicles are regressed before the ovulatory follicle associated with pregnancy is allowed to ovulate. Development of future estrous synchrony programs using small doses of progestins should focus on allowing for ovulation of typically growing dominant follicles or using larger doses of progestins to inhibit development of persistent ovarian follicles.

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Evaluation of Feather Meal for Calves Grazing Cornstalks

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Mark Klemesrud[1]

Calves grazing cornstalks can be expected to perform similarly on either a traditional soybean meal or a sunflower/feather meal supplement. The sunflower/feather meal supplement resulted in a saving of $0.05/hd/day.

Summary

Three years of cornstalk grazing trials were conducted from 1995-97 to determine the feeding value of a sunflower, feather and blood meal supplement compared to a traditional soybean meal supplement. Analysis revealed no year x treatment interaction in years 1 and 2, so data were pooled. Gains of calves receiving soybean meal (0.97 lb/day) were not significantly different from those consuming sunflower/feather meal (0.83 lb/day). In year 3, protein sources were evaluated for undegradable intake protein before formulation. Gains were similar between soybean meal (0.19 lb/day) and sunflower/feather meal (0.16 lb/day). A supplement containing sunflower/feather meal is an acceptable alternative to a soybean meal supplement while saving approximately $50-64/ton.

Introduction

Cornstalks are an excellent source of winter feed for growing calves. However, some type of protein supplementation is required, especially toward the end of the grazing period when corn grain becomes limited. Feather meal (FM), a byproduct of the poultry industry, has gained significant use by cattle producers in the past few years. Feather meal is an excellent source of undegradable intake protein (UIP) allowing for maximum winter gains based on forage availability and quality. In addition, FM is high in CP, allowing producers to deliver more total protein in a smaller package. While UIP is critical for growing calves, degradable intake protein (DIP) is equally important to maintain forage digestion by the rumen microbial population. Sunflower meal (SM), a source of DIP, lends itself as a carrier in the supplement and helps mask any possible palatability problems associated with FM. Blood meal (BM), another supplement high in CP and UIP, adds an excellent complementary amino acid profile which has been shown to be beneficial for young growing calves. A mixed supplement containing sunflower, feather and blood meals should result in calf gains equal to those of the more traditional, and expensive, supplement containing soybean meal (SBM).

The objective of this trial was to evaluate the feeding value of a sunflower/feather meal supplement when compared to soybean meal for weaned calves grazing winter corn residue.

Procedure

Three consecutive years of winter cornstalk grazing trials were conducted in 1994-95, 1995-96 and 1996-97 utilizing 279 crossbred weaned calves. In year 1, 99 calves were assigned to one of four dryland cornstalk fields in a randomized complete block design. Two fields assigned the SBM treatment included 29 and 18 head, while the two SM/FM fields contained 34 and 18 head. Head counts in each field were based on acreage and a previously determined dryland stocking rate of 1 animal/acre. In year 2, 90 calves were assigned to one of four dryland stalk fields in a randomized complete block design. Fields contained 23 and 24 head (SBM) and 28 and 15 head (SM/FM). Head counts were determined as described above. In year 3, 90 calves were

assigned randomly to one of eight irrigated stalk fields. Soybean meal fields contained 8, 11, 11 and 16 head while SM/FM fields contained 8, 11, 11 and 15 head. Head counts in each field were based on acreage and an irrigated stocking rate of 1.2 animals/acre. Each year, half of the fields in the study received 1.5 lb/hd (as-is, Table 1) of SBM supplement; the other half received 1.5 lb/hd (as-is, Table 1) of SM/FM supplement.

In year 3, residual corn estimations were made in each field prior to grazing by measuring 250 x 2.5 ft strips in four random locations. Whole and partial ears were collected and ears were shelled and the corn weighed to determine amount of residual corn in each field in bushels/acre.

In year 1, supplements were formulated to contain equal amounts of CP and UIP. The same supplement formulations were used in year 2; however, based on calf gains in both years, CP and *in situ* analyses were conducted following grazing in year 2 to evaluate supplement formulations compared to actual lab values. Based on this information, the SM/FM supplement was reformulated prior to grazing in year 3. The new formulation included 44.5% CP, 26% of which was UIP (DM basis), to more closely equalize supplements based on actual lab values. Prior to reformulation, both CP and *in situ* analyses were conducted on the protein sources of each supplement. These actual values for CP and UIP were used in the new formulation. Crude protein and *in situ* analyses were again performed on the mixed supplements following grazing.

For *in situ* analysis, ingredients and supplements were incubated in quadruplicate dacron bags, utilizing one steer maintained on a grass hay diet. All samples were incubated 16 hours. After incubation, bags were washed with warm rinse water until water ran clear, then dried for 48 hr at 140°F, and weighed. Residue was analyzed for N using a nitrogen analyzer. Crude protein values were determined by grinding ingredients and supplements and analyzing for N.

Animal performance was measured in terms of ADG. Both initial and final weights were based on the average of two consecutive day weights following three days of limit feeding at 2% of body weight. Calves were removed from fields when, based on visual appraisal, quantity of forage became limiting.

Table 1. Supplement compositions.

	Supplement, % DM			
	1994-96		1996-97	
Ingredient	SBM[a]	SM/FM[a]	SBM[a]	SM/FM[a]
SBM[a]	91.4	——	91.4	——
FM[a]	——	11.2	——	18.9
SM[a]	——	81.2	——	69.1
BM[a]	——	2.1	——	2.6
Urea	——	——	——	3.1
Dical	3.3	1.6	3.3	2.4
Vit. premix	.08	.08	.08	.08
Trace min. premix	.26	.26	.26	.25
Selenium	.18	.18	.18	.18
Salt	3.27	3.27	3.27	3.27
Rumensin 80	.14	.14	.14	.14
Pellet binder	1.36	——	1.36	——

[a]SBM = soybean meal; FM = feather meal; SM = sunflower meal; BM = blood meal.

Results

Because analysis showed no year x treatment interaction between years 1 and 2 (1994-95 and 1995-96), data were pooled across years. Gains for calves receiving SBM were not different than calves receiving SM/FM. Calves supplemented with SBM gained 0.97 lb/d, while calves consuming SM/FM gained 0.83 lb/d (Table 2). Following the analysis of supplements after grazing in year 2, the SBM was found to be 44% CP (DM basis), 42% of which was UIP. The SM/FM was 41% CP (DM basis), 33% of which was UIP. These results may explain why SBM calves gained numerically faster. Young calves require substantial UIP for maximum growth. The microbial population in calves is unable to supply adequate protein to the animal, even when maximum growth is not desired. Therefore, supplying calves with increased UIP should result in improved gains. As indicated by the above UIP values for each supplement, the SBM was supplying calves with slightly more UIP than the SM/FM, which likely resulted in the observed gains. While DIP values for SM/FM would have been higher, metabolizable protein supplied to the animal from microbial protein would likely be limited by energy from the corn residue. Assuming energy intake was equal in all fields, microbial CP supplied to calves would have been roughly equal in both treatments; however, based on UIP values, metabolizable protein would have been slightly greater for calves receiving SBM.

Table 2. Average daily gain of calves and residual corn estimates by year and treatment.

	ADG, lb/hd/day	
Year	Soybean meal	Sunflower/ Feather meal
1994-1995	.59	.46
1995-1996	1.34	1.20
Average, 1994-1996	.97	.83
1996-1997	.19 (.63)[a]	.16 (.52)[a]

[a]Residual corn estimations (bu/acre, as-is).

While the energy and protein interaction is important to animal performance, energy alone can have a large impact on gains. An important source of energy for cattle on corn residue is residual corn. Previous cornstalk grazing research at the University of Nebraska has shown residual corn can have a large impact on calf performance, with residual corn exhibiting a strong positive correlation with ADG. It is possible calves receiving SBM were grazing in fields containing more residual corn; however, no residual corn estimations were determined prior to grazing in years 1 and 2.

In year 3, efforts were made to resolve supplemental protein and residual corn questions. Formulation of

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the SM/FM supplement was revised to more closely match the SBM supplement and residual corn was measured after harvest, but prior to animal placement in fields. Calf gains in year 3 were similar for SBM (0.19 lb/d) and SM/FM (0.16 lb/d; Table 2). Likewise, residual corn estimates were similar with 0.63 bu/acre remaining in SBM fields while 0.52 bu/acre remained in SM/FM fields.

Economic analysis of both supplements from year 3 revealed that the SM/FM supplement was $64.40 less per ton than SBM. This resulted in a difference of $0.05/hd/d and a total savings of $3.87/hd over 80 days of grazing. However, due to the recently inflated price of SBM, these differences may be larger than normal. Utilizing prices from May 1996, an economic comparison for years 1 and 2 demonstrates a price difference of $50/ton, which may be more representative of SBM costs typically observed.

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Feather Meal as a Source of Sulfur Amino Acids for Growing Steers

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Feather meal, which can provide a portion of the sulfur amino acids required by growing cattle, is an excellent source of escape protein. However, additional methionine may further improve performance.

Summary

One-hundred twenty individually fed steer calves were used to evaluate feather meal as a source of sulfur amino acids. Treatment proteins included a urea control and meat and bone meal (6.4% of dietary DM) plus 0, 1, or 2% feather meal with incremental levels of rumen protected methionine. Adding feather meal to meat and bone meal resulted in a linear increase in gain. Likewise, rumen-protected methionine also improved gain. These results indicate feather meal can provide a portion of the sulfur amino acids lacking in meat and bone meal. However, additional methionine may further improve performance.

Introduction

To optimize production in growing calves, escape protein is often supplemented to meet the animal's metabolizable protein requirement. However, ruminants, like all animals, have requirements for metabolizable amino acids rather than protein. Sources of escape protein vary markedly in amino acid content, ultimately affecting protein utilization efficiency. Meat and bone meal (MBM), a good source of escape protein (55% of CP), is deficient in the sulfur amino acids. Additional methionine in a rumen protected form improved daily gain and protein efficiency in growing steers supplemented with MBM (1995 Nebraska Beef Report, pp. 9-11). Feather meal (FTH) is an excellent source of escape protein (60% of CP) and sulfur amino acids. However, feather meal contributes primarily cysteine rather than methionine.

While methionine is an essential amino acid, cysteine is not. Cysteine used for normal protein synthesis can be supplied from the diet or synthesized from methionine. When dietary cysteine intake is insufficient to meet the body's needs, methionine is converted to cysteine to meet this need. The reverse reaction, however, the conversion of cysteine to methionine, does not occur. Therefore, providing adequate levels of dietary cysteine may spare methionine from the cysteine biosynthetic pathway. Because of this, using supplements which satisfy the needs for cysteine allows expensive methionine supplements to be used with greater efficiency. The objective of this research was to evaluate FTH as a source of sulfur amino acids for growing cattle.

Procedure

A calf growth trial was conducted using 120 steer calves (502 lb) individually fed diets (DM basis) of 44% sorghum silage, 44% corncobs and 12% supplement (Table 1). The steers were assigned randomly to one of four treatments, which consisted of: 1) urea (control); 2) MBM; 3) MBM plus 1% FTH; and 4) MBM plus 2% FTH. The level of MBM (6.4%) was equal among the three supplements and formulated to supply 70 g/day of metabolizable protein. The low level of FTH (1%) was formulated to provide 30 g/day of metabolizable protein or 1.5 g/day of metabolizable sulfur amino acids. The high level of FTH (2%) was formulated to provide 60 g/day of metabolizable protein or 3.0 g/day of metabolizable sulfur amino acids. Feather meal replaced urea, corncobs and tallow so all steers consumed a diet containing 11.5% crude protein (DM basis).

Within each of the non-urea treatment proteins, steers were assigned randomly to amount of supplemental rumen protected methionine. These amounts were 0, 1, 2, 3, 4 and 6 g/day. Rumen protected methionine was supplied as Smartamine M™ (Rhône-Poulenc Animal Nutrition, Atlanta, GA). All steers were implanted with Compudose on day 1. Steers were fed individually (at an equal percentage of body weight) once daily using Calan electronic gates. Weights were collected before feeding on three consecutive days at the begin-

Table 1. Diet composition (% of DM).

Ingredient	Urea	MBM[a]	MBM+ 1% FTH[a]	MBM+ 2% FTH[a]
Base mix				
Sorghum silage	44.00	44.00	44.00	44.00
Corncobs	44.00	44.00	44.00	44.00
Supplement				
Meat and bone meal	—	6.43	6.43	6.43
Feather meal	—	—	1.02	2.03
Soybean hulls	2.06	2.06	2.06	2.06
Corncobs	4.80	1.20	.65	.10
Tallow	1.40	.50	.36	.22
Urea	2.16	1.22	.89	.57
Sodium chloride	.30	.30	.30	.30
Ammonium sulfate	.20	.20	.20	.20
Dicalcium phosphate	.99	—	—	—
Trace mineral premix	.05	.05	.05	.05
Vitamin ADE premix	.03	.03	.03	.03
Selenium premix	.01	.01	.01	.01

[a]Meat and bone meal, meat and bone meal plus 1% feather meal and meat and bone meal plus 2% feather meal.

Table 2. Average daily gain of growing steers fed treatment proteins (lb/day).

	Treatment Protein			
Supplemental methionine level (g/day)	Urea	MBM[a]	MBM+ 1% FTH[a]	MBM+ 2% FTH[a]
0	.59	.74	.88	1.03
1	—	.80	.88	1.04
2	—	.89	.89	1.14
3	—	.85	.92	1.07
4	—	.90	.94	1.17
6	—	.88	1.05	1.22
SEM	—	.04	.04	.04

[a]Meat and bone meal, meat and bone meal plus 1% feather meal and meat and bone meal plus 2% feather meal.

ning and end of the 84-day trial. Efficiency of sulfur amino acid utilization was calculated for each treatment as gain versus supplemental methionine intake, using the slope-ratio technique.

Results

Average daily gain increased in growing steers as metabolizable protein supply increased. Steers fed the urea control supplement gained .59 lb/day; addition of MBM improved gains to .74 lb/day (Table 2). Consistent with previous research, supplementation of rumen protected methionine to MBM further improved gains. Nonlinear analysis predicted a maximum gain for MBM of .89 lb/day with the addition of 1.5 g methionine.

Inclusion of 1% and 2% FTH to MBM improved daily gains linearly (.88 and 1.03 lb/day, respectively; Table 2). The 1% FTH, which was formulated to supply 1.5 g of sulfur amino acids, promoted gains similar to MBM plus 1.5 g rumen protected methionine. Although the improvement due to 1% FTH can be attributed to the additional sulfur amino acids, the greater response to 2% FTH may be due to a greater overall supply of metabolizable protein and amino acids.

The addition of rumen-protected methionine to the treatments containing FTH also improved daily gain. This suggests the additional metabolizable protein from FTH may be deficient in the amino acid methionine, rather than total sulfur amino acids.

These results indicate feather meal can provide a portion of the sulfur amino acids not available in meat and bone meal. However, additional methionine may further improve performance.

Cull Dry Edible Beans in Growing Calf Rations

Ivan Rush
Burt Weichenthal
Brad Van Pelt[1]

Cull dry edible beans included directly into the diets of growing calves may decrease intake and daily gain but improve feed efficiency.

Summary

Including cull dry edible beans into diets for steer calves in two yearly trials produced slightly different results. In the first year, calculated net energy levels were higher in diets with 5 or 10% dry beans and daily gains were equal or better than for the no-bean diets. In the second year, with equal net energy values in rations containing 0, 7.5 or 15% dry beans, daily gains and feed intake decreased linearly with dry bean additions. Feed efficiency was improved as bean level increased.

Introduction

Dry edible beans, either great northern or pinto beans, are a major cash crop in western Nebraska. Cracked and discolored beans, which are sorted out and not acceptable for human consumption, are available for animal feed. In some years an early frost or freeze stops bean growth before maturity, and although yields may be high, the beans are unacceptable for domestic markets. Other environmental factors, such as bean diseases or excessive rain at harvest time, can adversely affect bean quality for human consumption.

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Because of these factors, large quantities of cull beans are available each year. Dry edible beans have 22-24% crude protein, very little fat and are a relatively good source of energy. They contain undesirable proteins called phytohemagglutinins or lectins, and if fed uncooked, cause severe growth inhibition to non-ruminants. Lectins apparently cause problems in protein digestion in the small intestine. It is unclear how much, if any, of the lectins are destroyed by the rumen microorganisms and whether or not protein digestion is affected. It is known, however, that when large quantities of dry edible beans are fed to ruminants, severe scouring will occur.

The feed industry has used cull beans for years in range supplements, both as a protein source and a pellet binder. Because limited data is available on the nutritive value of dry edible beans, two trials were conducted to evaluate performance of steer calves fed cull dry edible beans.

Procedure

In a 1996 trial, 96 predominately black Angus steers weighing approximately 625 pounds each were randomly divided into 12 pens and one of three treatments was randomly assigned to each pen. The three treatments were 0, 5 and 10% dry edible beans. The rations, as shown in Table 1, consisted primarily of corn silage, alfalfa hay, corn and supplement. When utilizing an NEg value of 64 Mcal/cwt for dry beans, the calculated NEg of the rations were 49.0, 51.7 and 55.1 respectively for 0, 5 and 10% bean levels. At first, when the rations were balanced, the NEg level of the beans was not considered and as a consequence more corn was added to the 10% bean ration. The calculated level of crude protein in the rations varied from 12.1% with 5% dry edible beans to 12.6% for rations containing 0 and 10% dry beans. Actual bunk sample analyses revealed that the crude protein was slightly higher for all rations and averaged approximately 13% (Table 1). All rations were supplemented with 16 g of Rumensin per ton of ration dry matter.

In a 1997 trial, 95 black steer calves weighing approximately 572 pounds

Table 1. Rations for steer calves fed two levels of cull dry edible beans, 1996 trial.

	Dry beans in diet, % of DM		
	0	5	10
Ingredients, % of DM			
Corn silage	40	47	35
Alfalfa hay	26	14	11
Corn	30	30	40
Cull dry beans	0	5	10
Additive supplement[a]	4.0	4.0	4.0
Calculated DM Composition			
Crude protein, %	12.6	12.1	12.6
UIP, %	3.9	4.0	4.3
NEm, Mcal/cwt	76.4	80.3	84.3
NEg Mcal/cwt	49.0	51.7	55.1
Ca, %	.77	.64	.58
P, %	.29	.30	.33
Bunk sample crude protein, %	13.9	13.5	12.6

[a]Contained 420 g of Rumensin per ton of supplement.

Table 2. Rations for steer calves fed two levels of cull dry edible beans, 1997 trial.

	Dry beans in diet, % of DM		
	0	7.5	15
Ingredients, % of DM			
Corn silage	25.6	40.8	56.1
Alfalfa hay	46.9	37.0	27.1
Corn	25.7	12.9	0
Cull dry beans	0	7.5	15.0
Additive supplement[a]	1.8	1.8	1.8
Calculated DM Composition			
Crude protein, %	13.0	13.0	13.0
NEm, Mcal/cwt	73.9	73.6	73.2
NEg, Mcal/cwt	46.0	46.0	46.0
Ca, %	.80	.71	.62
P, %	.29	.30	.32
Bunk sample crude protein, %	13.9	13.1	15.7

[a]Contained 1,200 g Rumensin per ton of supplement.

Table 3. Performance of steer calves fed two levels of cull dry edible beans, 1996 trial.

	Dry beans in diet, % of DM		
	0	5	10
No. pens	4	4	4
No. steers	32	32	32
Initial weight, lb	622	627	624
Final weight, lb	955	966	993
ADG, lb	2.98[a]	3.03[b]	3.3[c]
DM intake, lb	20.1[a]	21.8[b]	20.0[a]
Feed/gain	6.73[a]	7.18[b]	6.04[c]
NEg/gain, MCal/lb	3.31	3.72	3.34

[a,b,c]Means with different superscripts on the same line are different (P < .01).

Table 4. Performance of steer calves fed two levels of cull dry edible beans, 1997 trial.

	Dry beans in diet, % of DM		
	0	7.5	15
No. pens	4	4	4
No. steers	31	32	32
Initial weight, lb	568	573	574
Final weight, lb	863	843	829
ADG, lb	2.42[a]	2.26[bc]	2.15[c]
DM intake, lb	19.6[a]	17.2[ac]	14.8[bc]
Feed/gain	8.07	7.62	6.92
NEg/gain, MCal/lb	3.71	3.51	3.18

[a,b,c]Means with different superscripts on the same line are different (P < .01).

each were randomly assigned to 12 pens for three treatments: 0, 7.5 and 15% dry edible beans. Rations are shown in Table 2 and were calculated to be similar in crude protein (13%) and net energy for gain (46 Mcal/cwt) by varying the levels of corn silage, corn, alfalfa hay and dry edible beans. In this trial, it was assumed the dry edible beans had an NEg value of 64 Mcal/cwt (1984 NRC). It was decided to balance the diets to be isonitrogenous and isocaloric. Consequently, it was necessary to alter the level of ingredients in each ration. Analyses of bunk feed samples showed crude protein levels similar or higher than the calculated values. Rumensin was included at 23 g per ton of ration dry matter.

In both trials, calves were weighed in the morning before feeding on two consecutive days at the start and termination of the trial. These weights were averaged to determine the starting and ending weights. The trials were conducted for 112 and 121 days in 1996 and 1997, respectively. In 1996 the calves grazed cornstalks with alfalfa hay supplementation before the trial; in 1997, calves were fed a high roughage ration between purchase and the start of the trial.

The source of beans was a local bean processor selling cull dry edible beans. They contained 24.7% crude protein, .20% calcium and .51% phosphorus (on dry matter basis). The beans were either cracked or had discolored seed coats.

Results

In the 1996 trial, cattle receiving 10% cull beans gained faster than those fed 0 or 5% beans (Table 3). This might be expected, as the estimated energy concentration of the ration was higher for the ration containing 10% beans. It is unclear, however, why the gain of the cattle consuming 5% beans was not directly between those cattle consuming 0 and 10% beans. One likely reason: the rations containing 0 and 5% beans contained 30% corn, while the 10% bean ration contained 40% corn. Perhaps the additional corn provided more utilizable energy and the 5% beans did not provide the quantity of available energy the ration NEg would predict. When the quantity of net energy needed per unit of gain was calculated, there was no difference in the amounts required in the control and 10% bean rations. The ration containing 5% beans, however, appeared to require more net energy to produce a pound of gain. The steers fed 5% cull beans consumed more total ration than those fed either of the other diets. Feed required per pound of gain was lowest for cattle fed 10% cull beans and highest for the controls. Perhaps the added corn offset any objectionable qualities the 10% beans may have provided. It is not clear why the cattle fed 5% cull beans consumed more than controls and yet when 10% beans were fed, intake was the same as the control. Also, there were no apparent digestive problems with 10% cull beans as evaluated by feed intake and consistency of feces.

In 1997, as the level of beans increased in the ration, the gains and feed intakes decreased linearly ($P < .01$). Feed efficiency, however, improved as level of beans increased. Decrease in performance could have been from the possible effect of lectins on protein destruction in the small intestine, lower levels of energy in beans than was assumed or some other attribute that decreased the palatability of the rations containing beans. The levels of corn, corn silage and alfalfa also varied and it is possible that different combinations or levels affected palatability and cattle performance. It is questionable if this caused problems, however, because all of these ingredients are highly palatable. Based on calculations of feed utilization, it appears the energy value of beans is much higher than the assumed 64 Mcal/cwt. Because feed efficiency was improved, it appears the largest effect of the beans was related to ration intake. Perhaps cull dry edible beans could be used as an appetite inhibitor and may be beneficial in rations where limit feeding is desired. The 1997 trial indicates incorporation of these beans into growing rations results in intake and daily gain decreases along with improved feed efficiency.

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Comparative Calf Grazing of Corn and Soybean Residues

D. J. Jordon
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Mark Klemesrud[1]

Soybean residues are higher in crude protein, lower in digestible energy and have only one-third the carrying capacity of corn residues.

Summary

A grazing trial was conducted in the winter of 1996-97 to compare the feeding value of soybean stubble to that of cornstalks. Irrigated bean residues were stocked at 0.5 animals/acre, while irrigated corn residues were stocked at 1.2 animals/acre. Calves grazing cornstalks gained (0.17 lb/day) faster (P = .003) than calves consuming soybean stubble (-0.03 lb/day). In addition, calves grazing cornstalks remained in fields 14 days longer. Diet samples were collected on both corn and soybean residues. Ruminally fistulated steer calves grazing bean stubble consumed diets high in crude protein (12-25%), but low in organic matter digestibility (40-46%). Calves grazing cornstalks consumed diets from 5-6% crude protein and 60-65% digestibility.

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Introduction

While cornstalks are widely utilized by cow/calf producers for winter grazing, many acres of bean residue are either not utilized or utilized only as a consequence of previously existing fence surrounding both corn and bean fields. Cattle are allowed to run on bean stubble simply because it is easier for the producer to allow animals access to a bean field rather than fence it from an adjacent corn field. Observations suggest cattle spend considerable time foraging in bean residue; however, no studies have been conducted to determine the diet quality the animals select. Although previous study has shown calves grazing corn residue gained faster than calves grazing a combination of soybean stubble and cornstalks (1997 Nebraska Beef Cattle Report, pp. 26-27), it is unclear how long calves may be wintered on solely bean residue (2 acres/animal) without drastically impacting performance.

The objectives of the present trial were to evaluate the feeding value of soybean residue compared to corn residue, to estimate carrying capacity of bean residues and to determine the diet quality selected by calves grazing winter corn and bean residues.

Procedure

From November 22, 1996 through January 31, 1997, 123 weaned, crossbred steer calves (540 lb) were used in a randomized complete block design to compare the feeding value of soybean and corn residue. Calves were assigned randomly to one of 12 irrigated residue fields. Eight corn fields contained 16, 15, 11, 11, 11, 11, 8 and 7 head. Four bean fields contained 12, 9, 6 and 6 head. Head counts in corn fields were based on acreage and an irrigated corn residue stocking rate of 1.2 hd/acre. Residual corn estimations were determined in corn fields. Estimations were determined by collecting whole and partial ears from an area 250 x 2.5 ft. Head counts in bean fields were based on acreage and an irrigated bean residue stocking rate of 0.5 hd/acre, based on the amount of available pod DM in bean fields (1997 Nebraska Beef Cattle Report, pp. 26-27).

Throughout the grazing period, calf weights from one corn field and one bean field were monitored to determine when the weight of cattle grazing bean residues began deviating from cattle grazing cornstalks. Individual weights were taken three times weekly and plotted. Weights were taken using two portable automatic scales: one set up in the corn field; the other was placed in the bean field.

Animal performance was measured in terms of ADG. All initial cattle weights and final weights on cattle grazing corn residues were based on the average of two consecutive day weights following three days of limit feeding at 2% of body weight. Final weights for the cattle grazing bean residues were simply a one day weight upon removal from fields. Based on weights obtained from the automatic scales, cattle on the bean residue were removed two weeks earlier than calves grazing cornstalks.

Diet samples were collected using four ruminally fistulated steer calves (525 lb). Two of the four were maintained on a corn field; the remaining two calves were maintained on a bean field. Calves were allowed a one week adaptation to their respective fields prior to the first collection. In addition, all four calves were supplemented with 6 lb/hd (DM basis) of wet corn gluten feed each day. Supplementation was necessary in order to maintain condition and animal health of the calves due to the cold conditions during ruminal evacuations. Diet samples were collected following complete rumen evacuations. Calves were allowed a 30 minute grazing period, sampled and rumen contents replaced. While an attempt was made to collect diet samples twice weekly, weather often dictated when samples were taken. Diet samples were freeze dried, ground and analyzed for CP and IVOMD.

All calves were supplemented once daily with either a soybean meal or a sunflower/feather meal supplement (44% CP, DM basis) at 1.5 lb/hd (DM basis). Although this supplementation regime was another factor in the trial, no statistical differences were found based on protein supplementation and data were pooled across supplements.

Results

Calves grazing corn residue gained more weight ($P = .003$) than those on soybean stubble. However, calves wintered on soybean residue did maintain their initial weight over the 71 days of grazing and stayed healthy. Calves grazing cornstalks did not perform as well as in previous years; however, this is likely a function of a lesser amount of residual corn remaining in fields in the winter of 1996-1997 and a few weeks of cold weather. Average estimates place residual corn grain at 4.2% of the corn yield, and yields for 1996-97 averaged 138 bu/acre (as-is). In an average year, then, 5.8 bu/acre (as-is) of residual corn could be expected to remain in the fields after harvest, compared to the 0.58 bu/acre (as-is) actually found in 1996-97. Figure 1 illustrates a second order polynomial line fit to the average weekly calf weights on both corn and soybean residues throughout the trial. Based on the graph, it appears calves grazing soybean residue did not begin to deviate in weight from calves on cornstalks until the first of January. However, calves grazing corn residue can typically be expected to gain 1 lb/d; calves in this trial gained only 0.17 lb/d. Assuming the soybean residues in this particular year were of 'average' quality, calf gains must not be expected to be as similar for corn and soybean residues in most years as was experienced in the present trial.

Figure 2 shows the CP of both the corn and soybean diets selected by calves throughout the trial. A treatment x time interaction was detected ($P<.0001$), because the CP values for diets selected from bean residues initially declined compared to increases in corn residues. Differences between CP in corn and bean residues were noted from December 14 through December 22 ($P<.05$) as calves consuming bean residues were likely consuming beans remaining on the pods. This is supported by visual observations of both whole beans and pods found in the diet samples. However, no differences were found on

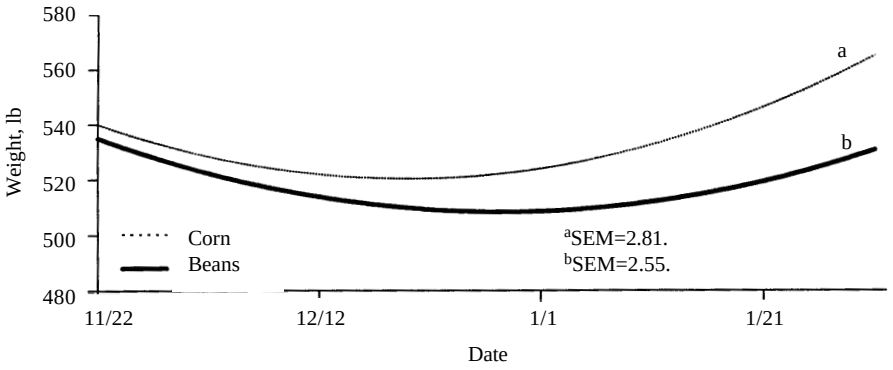

Figure 1. Weekly weights of calves grazing corn or soybean residues.

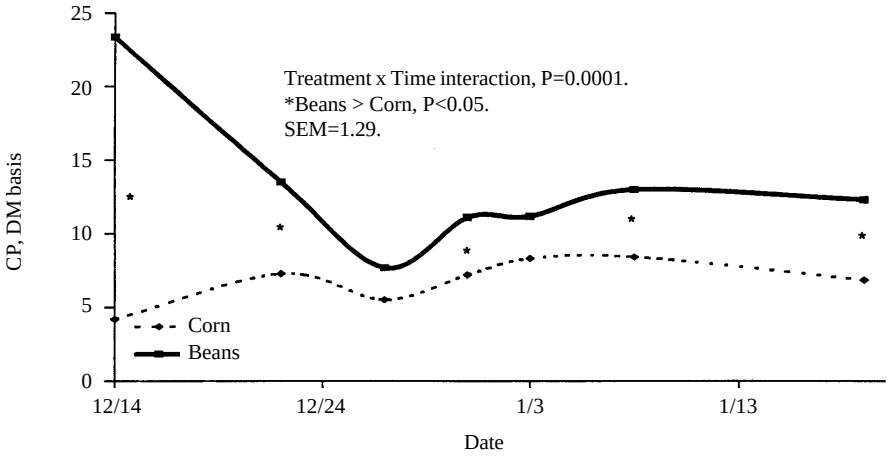

Figure 2. Crude protein of winter corn and soybean residues.

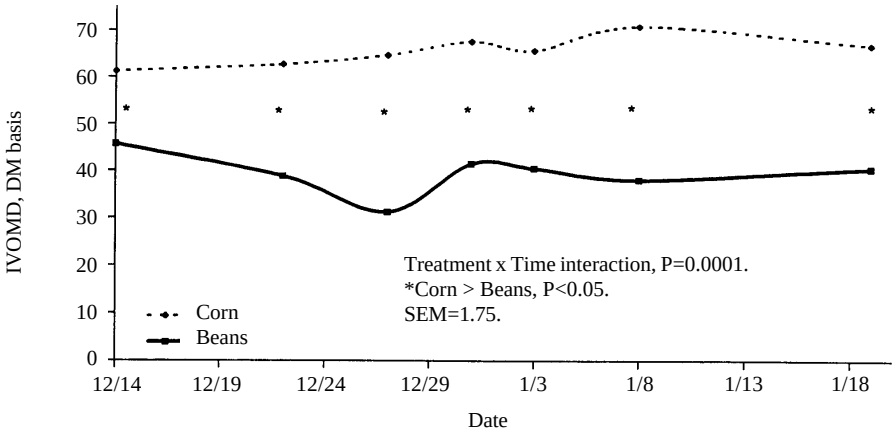

Figure 3. In vitro organic matter disappearance of winter corn and soybean residues.

December 27, as there was a light snow cover on the ground which would have inhibited selection of beans and pods. From that time, crude protein values were generally five units greater for bean residues compared to corn through the end of the trial.

Crude protein values increased (P<.05) initially from 4.2 to 7.3% CP (DM basis) for calves grazing corn residues. Diets from bean residues initially declined (from 23.4 to 7.7% CP, DM basis; P<.05) through December 27, then slightly increased (from 7.7 to 11.1% CP, DM basis; P<.05) through December 31, and remained constant through the end of the trial.

While the CP values of diets selected by calves consuming soybean residues were high, IVOMD values (Figure 3) were low. Analysis of IVOMD values showed a treatment x time interaction (P<.0001) as corn residues generally increased in IVOMD, while, in time, bean residues generally decreased in IVOMD. Corn residues were consistently greater (P<.05) in IVOMD compared to bean residues selected by fistulated steers throughout the trial. Variations in bean residue IVOMD values from December 22 through December 27 were likely due to a light snow cover.

In vitro organic matter digestibility values for bean residues (Figure 3) were lower than expected. Values this low would not be expected to support maintenance. Last year, IVOMD values for pods were 64% (DM basis; 1997 Nebraska Beef Cattle Report, pp. 26-27) and whole beans were highly digested. If the calves were consuming pods and beans early in the grazing period, IVOMD values should have been above 64%. The lower values observed in this trial may be due to consumption of leaves and stems, which are much lower in digestibility than pods. It is also possible that soybean fat was not accounted for in the IVOMD procedure and may have been measured as undigested. This would underestimate the digestibility values for the diets, and, because the fat is higher in energy than carbohydrates, would also underestimate the digestible energy content of the soybean residue diets.

Analysis of either corn or bean IVOMD values over time showed corn residue diets selected by fistulated steers varied throughout the trial, but generally remained constant over the first two weeks of the trial and then increased (from 64.6 to 67.6% IVOMD, DM basis; P<.05) from December 27-31, then remained constant until a decrease in the last two weeks of the trial (from 70.8 to 66.8% IVOMD, DM basis; P<.05). Other cornstalk grazing research has shown IVDMD values are roughly 60% (DM basis) after 40 days of grazing when residual corn has been consumed. Calves in this trial consumed relatively constant diets containing

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about 60-65% digestible organic matter (DM basis) and IVOMD values did not significantly decline until the last two weeks of the trial. This supports previous work which indicated residual corn estimations show a significant decline in IVDMD values 3-4 weeks into the grazing period, after residual corn has been consumed. Bean residue values initially declined ($P<.05$) from 45.7 down to 31.2% IVOMD (DM basis) in the first two weeks of the trial, then increased ($P<.05$) to 41.4% IVOMD (DM basis) from December 27-31, remaining constant through the end of the trial. Again, the decline in IVOMD around December 27 was likely due to snow cover during grazing. Without the December 27 collection, it is likely no time differences in terms of IVOMD would have been found for the bean stubble.

In this particular year, while calves grazing bean residue did maintain weight and health at a stocking rate of 2 acres/animal, still more acres (2.4) appear required to carry calves as long as calves grazing corn residue at a stocking rate of 0.8 acres/animal. In addition, calves grazing bean residue may be more limited by the digestible energy of the residue than available residue, based on IVOMD values obtained in the present trial.

The higher protein content of soybean residue would complement the lower protein-higher energy contents of the corn residue when both are grazed simultaneously. Therefore, it appears soybean residue has some value for both calves and cows. However, the energy value is lower and about three times as many acres would be needed in order to carry an animal on solely soybean residue compared to corn residue.

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Solvent-Extracted Germ Meal for Receiving Calves

Daniel Herold
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Terry Klopfenstein
Todd Milton
Rick Stock[1]

Calves fed solvent-extracted germ meal blended with corn bran and steep liquor in a receiving diet exhibited satisfactory performance and intake.

Summary

This study evaluated solvent-extracted germ meal as a dietary ingredient for receiving calves. Treatments were 7% of dry matter as either corn bran or solvent-extracted germ meal in 55% concentrate diets. Average daily gain, dry matter intake and feed to gain ratio were not influenced by treatment. Dry matter offered for the first 7 days calves were in the feedlot also did not differ due to treatment. Both dry matter consumption and calf performance indicated solvent-extracted germ meal can replace up to 7% corn bran in the diet without influencing either dry matter intake or performance.

Introduction

Calves entering a feedlot are very susceptible to respiratory diseases due to the combined stress of weaning, shipping, being mixed with cattle from different origins and adapting to a new environment. Good vaccination and antibiotic programs are effective in combatting the incidence and severity of respiratory disease, but perhaps the most crucial factor contributing to reduced calf morbidity and mortality is adequate nutrition.

Unfortunately, during the first few days following arrival at the feedlot, calves will typically eat less than 50% of their normal feed intake and are hesitant to consume feedstuffs they are unaccustomed to. Therefore, receiving diets for calves must be a concentrated source of high-quality protein, digestible energy, vitamins and minerals to approach meeting requirements when intakes are low. Byproducts of the wet corn milling industry can serve as components of receiving diets. These byproducts provide both protein and energy and also can be economical alternatives to corn. Corn bran and corn steep liquor combined produce wet corn gluten feed, which has been demonstrated to be an acceptable ingredient in calf receiving diets (1995 Nebraska Beef Report, pp. 28-30). Solvent-extracted germ meal, a byproduct of corn oil production, has not been readily available to Nebraska cattle producers. However, this product could constitute an additional energy source for ruminant diets, either alone or blended with corn bran and(or) steep liquor. The objectives of this research were to determine if solvent-extracted germ meal can serve as a dietary ingredient for receiving calves without diminishing intakes and performance, as well as to assess acceptability of this byproduct in the first week of feeding.

Procedure

Between October 14 and November 15, 1996, 785 medium-framed steer calves (448 lb) were blocked by source

Table 1. Diets used in the receiving trial (% of DM).

Ingredient	Treatment	
	SEGM[a]	BRAN[b]
Dry-rolled corn	31.00	31.00
Alfalfa hay	30.00	30.00
Grass hay	15.00	15.00
Corn steep liquor	7.00	7.00
Dry corn bran	7.00	14.00
Solvent-extracted germ meal	7.00	——
Corn gluten meal	2.45	2.45
Salt	.30	.30
Limestone	.10	.10
Tallow	.10	.10
Trace minerals[c]	.03	.03
Vitamin premix[d]	.02	.02

[a]Solvent-extracted germ meal.
[b]Dry corn bran.
[c]10% Mg, 6% Zn, 4.5% Fe, 2% Mn, .5% Cu, .3% I, and .05% Co.
[d]15,000 IU vitamin A, 3,000 IU vitamin D, and 3.75 IU vitamin E per gram of premix.

and assigned randomly to one of two dietary treatments. Treatments were 7% of the diet DM, comprised of either solvent-extracted germ meal (SEGM) or dry corn bran (BRAN) added to a blend of 7% steep liquor and 7% BRAN (Table 1). Therefore, corn byproducts comprised 21% of dietary DM, which was balanced to provide a minimum of 13.5% CP, .5% Ca, .3% P, .6% K and 45% roughage. Calves originated from sale barns or were purchased directly from Nebraska ranches. Loads received early in the day were processed before feeding; those arriving late were fed grass hay, allowed access to water and processed early the next day. Processing procedures involved vaccination for respiratory disease, treatment for internal parasites, weighing, application of identification tags and alternately sorting animals into one of two pens as they exited the chute. A total of nine loads of cattle were received from different sources, allowing 15 pens per treatment.

On day 1 of the receiving trial, calves were enticed to the bunk with one small square bale of grass hay per pen, in addition to the 6 lb DM of dietary treatment per animal. No grass hay bales were offered thereafter. However, calves were allowed to consume any baled grass hay remaining in the bunk after the first day. Treatment diet DM to be fed was determined each morning to allow ad libitum access to treatment diets while minimizing orts. Calves were offered the receiving diet treatments for an average of 28 days. During the last four days, calves were limit-fed their respective treatments at an estimated 2% of body weight (DM basis) to minimize animal weight variation due to fill, and final weights were obtained.

Throughout the receiving trial, calves were observed daily for signs of sickness. Those showing signs of respiratory disease or exhibiting feeding indifference were removed from their pen and checked for elevated body temperature. Calves with a rectal temperature above 103.5°F were treated with long-acting antibiotic at three-day intervals or until body temperature returned to normal. Animals exhibiting signs of severe illness were pulled from their pen, housed where they could be frequently observed and the treatment diet was offered. However, intakes of ill animals did not contribute to treatment data until they were returned to their home pen in improved health, typically within three days.

Results

Calves in both treatments performed exceptionally well throughout the feeding period. Average daily gain for SEGM (2.60 lb) and BRAN (2.49 lb) treatments were similar (P=.22, Std err=.06). Calves assigned to the 7% BRAN treatment consumed an average of 13.35 lb of DM daily, which was not different than 13.12 lb of DM intake exhibited by the 7% SEGM cattle (P=.19, Std err=.12). Daily dry matter delivered for the first week calves were in the feedlot was an indication of diet acceptability. Unlike DM intake data, DM delivery data do not account for weight of DM remaining in the bunk. Orts present at the time bunks were read were appraised visually without being collected and DM offered adjusted as necessary. For the first seven days calves were in the feedlot, the average daily DM delivered did not differ due to treatment (P=.67, Std err=.21). The SEGM treatment was delivered at an average rate of 7.42 lb per calf daily in the first week of the trial; the DM delivery associated with the BRAN diet was 7.55 lb per calf. Similar DM delivery during the first week suggests calves accepted both blends of byproducts equally at this dietary level. Due to a numerically higher average daily gain and lower DM intake, calves consuming the SEGM diet appeared to have a more favorable feed to gain ratio (5.04) than those assigned to the BRAN treatment (5.37). Analysis of these data approached significance (P=.10) suggesting SEGM may contain more energy than BRAN. This, however, is difficult to conclude at this level of dietary inclusion.

Calf mortality was not influenced by treatment. Two calves from the same load, but assigned to different treatments, died within four days of receiving due to advanced respiratory disease. Of calves assigned to the BRAN treatment, 49 were pulled and treated due to elevated temperatures, whereas 61 calves assigned to the SEGM diet were likewise treated. This level of calf morbidity resulted in 12.5 and 15.6% of the BRAN and SEGM calves being treated, respectively.

Results of this study showed that SEGM can replace a portion of BRAN in calf receiving diets without diminishing performance or DM intake. Calves consumed SEGM and BRAN diets to the same extent during the critical first week after arriving at the feedlot and exhibited exceptional gains and health throughout the receiving period. Feeding corn byproducts as a portion of the dietary concentrate in receiving diets can diminish the need for corn and increase use of alternative feedstuffs not acceptable for use in the production of nonruminant species.

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[1]Daniel Herold and Mark Klemesrud, research technicians; Terry Klopfenstein, Professor, Todd Milton, Assistant Professor, Animal Science, Lincoln; Rick Stock, Cargill Corn Milling, Blair, NE.

Solvent-Extracted Germ Meal, Corn Bran and Steep Liquor Blends for Finishing Steers

Daniel Herold
Mark Klemesrud
Terry Klopfenstein
Todd Milton
Rick Stock[1]

Solvent-extracted germ meal can be an effective ingredient for finishing cattle and may interact with steep liquor/distillers solubles-corn bran blends to improve efficiency.

Summary

Three trials evaluated solvent-extracted germ meal for finishing ruminants. Dry corn bran and steep liquor/distillers solubles were fed in combination with solvent-extracted germ meal to evaluate interactions of byproduct blends. Byproducts enhanced intake and gain relative to dry-rolled corn diets. Adding tallow to byproduct diets increased efficiency. Feeding solvent-extracted germ meal with steep liquor heightened performance, but the benefit diminished when steep liquor level reached 30% of dry matter. Including solvent-extracted germ meal with wet corn gluten feed influenced neither daily gain nor intake. Results show solvent-extracted germ meal, either alone or blended with steep liquor/distillers solubles and dry corn bran, is an effective energy source for finishing cattle.

Introduction

The process of wet milling corn yields fructose or ethanol from corn starch and oil from corn germ. Byproducts of the wet milling industry include dry corn bran, steep liquor, distillers solubles and solvent-extracted germ meal. After the oil is removed from corn germ, solvent-extracted germ meal may be marketed as a component of corn gluten feed or sold as a feed ingredient.

Finishing cattle can be more efficient when corn byproducts are fed in combination with dry-rolled corn compared with dry-rolled corn alone. Replacing a portion of the dietary starch from corn with the fibrous energy of corn byproducts may alleviate the severity of subacute acidosis. However, different ratios of solvent-extracted germ meal, dry corn bran and steep liquor may influence cattle performance due to dietary energy content and effects on intake. The objectives of this research were: 1) to determine performance and intake associated with solvent-extracted germ meal diets with and without steep liquor/distillers solubles; and 2) to ascertain if solvent-extracted germ meal could serve as a component of wet corn gluten feed when blended with dry corn bran and steep liquor.

Procedure

Trial 1

Large framed steer calves (n=160, 595 lb) were used in a finishing trial averaging 169 days. Solvent-extracted germ meal (GM), with and without corn steep liquor/distillers solubles (ST), was evaluated relative to diets containing dry-rolled corn (DRC) and wet corn gluten feed (WCGF). Nutrient composition of GM was 91% DM, 21% CP, 60% NDF, .04% Ca, .33% P and .38% K. Calves were blocked by weight and randomly assigned to one of four treatments. Treatments were DRC control, or either 9% GM, 19%GM+19%ST or 38% WCGF replacing DRC. Final finishing diets contained 92.5% concentrate (Table 1). The WCGF used in this trial was produced by Cargill Corn Milling, Blair, NE. Calves were acclimated to finishing diets with four adaptation diets containing 45, 35, 25 and 15% roughage, fed for 3, 7, 7 and 7 days, respectively. Steers were implanted with Revalor-S on day 1 and day 90 of the trial and fed once daily in groups of 10 animals per pen. Diets were formulated to contain a minimum of 11.5% CP and to meet the rumen degradable protein requirement (TDN $\times$ .081) according to 1996 NRC Nutrient Requirements of Beef Cattle.

Trial 2

Medium framed yearling steers (n=60, 780 lb) were used in a 118-day finishing trial to evaluate combinations of GM and ST. The trial was initiated on August 8, 1996 when steers were removed from smooth bromegrass pastures. Yearlings were assigned randomly to one of 10 dietary treatments, allow-

Table 1. Composition of diets used in Trial 1.

	Diets (% of DM)[a]			
Item	DRC	9%GM	38%WCGF	19%GM,19%ST
Dry-rolled corn	83.5	74.5	50.3	50.3
Ground corncobs	7.5	7.5	7.5	7.5
Wet corn gluten feed	—	—	38.2	—
Germ meal	—	9.0	—	19.1
Steep	—	—	—	19.1
Liquid 32[b]	5.0	5.0	—	—
Supplement[c]	4.0	4.0	4.0	4.0

[a]DRC = dry-rolled corn control, GM = solvent-extracted germ meal, WCGF = wet corn gluten feed, ST = steep liquor/distillers solubles.
[b]Molasses, urea supplement with 50% CP (DM basis).
[c]Contains minerals, vitamins, Rumensin and Tylan in a finely ground corn carrier.

ing six animals per treatment. Treatments consisted of a DRC control and combinations (% of diet DM) of either 0, 15 or 30% ST blended with either 15, 30 or 45% GM to replace an equal proportion of the DRC dry matter. Steers were housed in a covered confinement facility with southern exposure and individually fed once daily using Calan gates. Blends of GM and ST in ratios of 50:50, 75:25, 67:33 and 60:40 (DM basis) were mixed the day before feeding. This allowed the ST to permeate the GM, simulating an equilibrated blend which had been produced at the mill and transported to the feedlot. Initial mixes were used as individual ingredients in diet preparation. Additional ST and all other ingredients within each treatment were individually weighed and mixed using a Data Ranger at feeding.

Steers were implanted with Revalor-S on day 1 of the study. Adaptation to the high-concentrate diets was accomplished over 21 days. Adaptation diets contained 45, 35, 25 and 15% ground alfalfa hay (DM basis) and were fed for 3, 4, 7 and 7 days, respectively. The ratios of dry-rolled corn to the ST:GM blends were maintained throughout the adaptation diets. Finishing diets contained 7.5% ground alfalfa hay, 25 g/ton Rumensin, 10 g/ton Tylan, trace minerals, supplemental vitamins A, D, and E and were formulated to provide at least 12.0% CP, .7% Ca, .35% P and .6% K (DM basis).

Trial 3

Large framed steer calves (n=306, 659 lb) were fed for an average of 153 days to determine the performance when fed eight different blends of ST, GM and(or) dry corn bran (BR) replacing a portion of the DRC in a 92.5% concentrate finishing diet. Cattle were blocked by weight into one of four blocks and randomly assigned to treatment. Two blocks had eight steers per pen; the remaining blocks contained nine, yielding four pens with 34 steers per treatment. Calves were implanted with Revalor-S on day 1 and re-implanted on day 68. Diets were formulated to provide a minimum of 12.5% CP, .7% Ca, .3% P and .6% K and contained 25 g/ton Rumensin and 10 g/ton Tylan (Table 2). Treatments were: 1) DRC control; 2) 67%BR,33%ST; 3) 67%GM, 33%ST; 4) 50%BR,50%ST; 5) 50%GM, 50%ST; 6) 50%ST,25%BR,25%GM; 7) 50%ST,25%BR,25%GM+fat (tallow at 3% of dietary DM); 8) 33%BR, 33%GM,33%ST; and 9) 33%BR, 33%GM,33%ST,+fat. Byproduct blends were included to comprise 22.5% of diet DM. As in Trial 2, cattle were adapted to grain using 45, 35, 25 and 15% roughage diets. However, in Trial 3 calves were fed each adaptation diet for 7 days, and only the DRC to alfalfa ratio was changed with each diet. The dietary percentage of ST, GM and BR blends (22.5% of DM) was consistent throughout the trial.

For initial weights in all trials, steers were limit fed at 2% of body weight (DM basis) for 5 days to reduce fill differences and weights were obtained before feeding on two consecutive days. Final live weights were determined by dividing hot carcass weight by a common estimated dressing percentage (62). Data were also collected for fat thickness over the twelfth rib, quality grade yield grade, and the incidence of liver abscesses.

Results

Trial 1

Dry matter intake and ADG of cattle fed the 38%WCGF treatment were higher (P<.05) than all other treatments (Table 3). However, there were no differences among other treatments for daily gain or intake. Average daily gain of cattle fed the GM:ST blend was greater (P<.05) than that for steers consuming GM without ST, which had gains similar to the DRC control. Orts collected from pens receiving the 9% GM diet appeared to have a higher proportion of GM than was present in the initial diet. It is unclear whether steers were actively sorting out the GM or if the dry, finely ground product was settling in the bunk. In either case, the integrity of the dietary balance of this treatment was compromised with the diminished consumption of GM, which

(Continued on next page)

Table 2. Diets used for finishing calves in Trial 3.

	Diet (% of DM)[a]								
Item	DRC	67%BR 33%ST	67%GM 33%ST	50%BR 50%ST	50%GM 50%ST	50%ST 25%BR 25%GM	50%ST 25%BR 25%GM + Fat	33%BR 33%GM 33%ST	33%BR 33%GM 33%ST + Fat
Dry-rolled corn	84.7	62.9	63.2	63.2	63.2	63.2	60.2	63.2	60.2
Alfalfa hay	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5
Dry corn bran	—	15.0	—	11.25	—	5.62	5.62	7.5	7.5
Steep	—	7.5	7.5	11.25	11.25	11.25	11.25	7.5	7.5
Germ meal	—	—	15.0	—	11.25	5.63	5.63	7.5	7.5
Molasses	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Tallow	—	—	—	—	—	—	3.0	—	3.0
Supplement[b]	2.8	2.1	1.8	1.8	1.8	1.8	1.8	1.8	1.8

[a]DRC = dry-rolled corn, BR = dry corn bran, ST = steep liquor/distillers solubles, GM = solvent-extracted germ meal, Fat = tallow.
[b]Contains Vitamin A, D, and E premix, minerals, Rumensin-80 and Tylan.

could have lowered CP intake while increasing starch consumption.

The DRC control treatment exhibited a less efficient feed/gain ratio (P<.05) than treatments containing corn byproducts. Feed-to-gain ratio for 19%GM,19%ST (5.37) and 38%WCGF (5.51) treatments did not differ, indicating that in this trial, 50:50 blends of both BR and GM with ST had similar energy values. Feed-to-gain ratio attributed to the 9% GM diet was numerically greater than, but not different from, the 38%WGCF treatment (P=.23).

When ST and GM were combined, the GM was adhered to other dietary ingredients by the ST, diminishing the separation potential and enhancing performance. Carcass quality and yield grades were greatest for the 38% WCGF diets but did not differ among other treatments.

Trial 2

Due to diet separation problems, Trial 2 was designed to test for a possible GM effect on intake, and to further investigate the possibility of a dietary interaction between GM and ST. A GM by ST level interaction was found for both average daily gain and DM intake (P<.05). Steers consuming 0 and 15% ST gained similarly across all levels of GM (Figure 1). Gains associated with the 30% ST treatment declined at the 30 and 45% GM levels. Means for DM intake did not differ among the 15, 30, or 45% GM treatments within the 0 and 15% ST levels. However, a linear decrease in DM intake was demonstrated within the 30% ST treatment as level of GM increased from 15 to 45% (P<.05) (Figure 2). An additional ST by GM level interaction was observed for quality grade, with 30%ST,30%GM and 30%ST,45%GM treatments exhibiting the lowest values for carcass quality grade.

Average daily gain for DRC (3.12 lb) was exceeded by the 15 (3.97 lb), 30 (3.90 lb), and 45% (3.93 lb) GM levels with the inclusion of 15% ST (P<.05). No differences were observed among DRC and GM, ST blends at any level for feed conversion. No liver abscesses were encountered in this study.

Table 3. Effect of diets on calf performance in Trial 1.

	Diets[a]			
Item	DRC	9% GM	38% WCGF	19% GM,19% ST
Daily gain, lb	3.36[b]	3.36[b]	3.90[c]	3.66[d]
DM intake, lb/day	19.72[b]	18.99[b]	21.48[c]	19.67[b]
Feed/gain[e]	5.88[b]	5.64[c]	5.51[cd]	5.37[d]
Quality grade[f]	18.47[b]	18.12[b]	18.95[c]	18.38[b]
Yield grade	2.3[b]	2.2[b]	2.8[c]	2.5[d]
Fat thickness, in	.43[b]	.43[b]	.53[c]	.47[bc]

[a]DRC = Dry-rolled corn control, GM = solvent-extracted germ meal, WCGF = wet corn gluten feed, ST = steep liquor/distillers solubles.
[b,c,d]Means within row with unlike superscript differ *P*<.05.
[e]Analyzed as gain to feed, the reciprocal of feed to gain.
[f]High select = 18, low choice = 19.

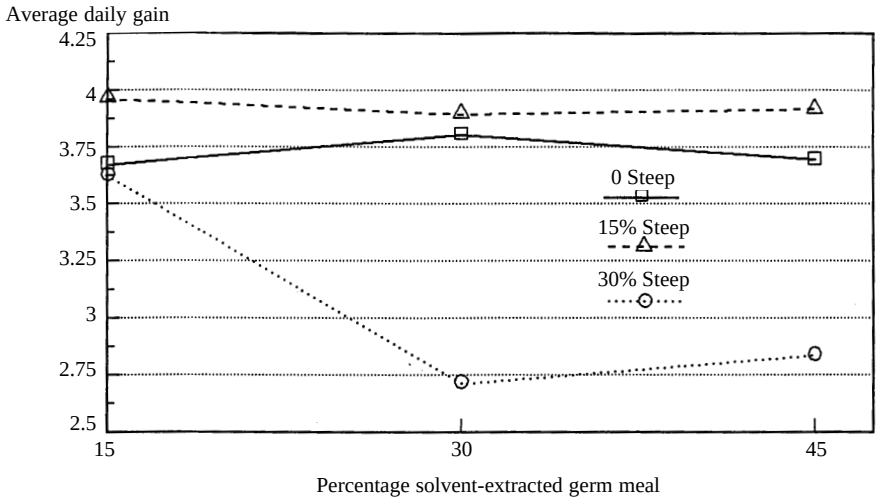

Figure 1. Solvent-extracted germ meal by steep liquor/distillers solubles level interaction exhibited for ADG by yearlings steers in Trial 2 (P<.05). Dry-rolled corn control cattle gained an average of 3.12 lb per day.

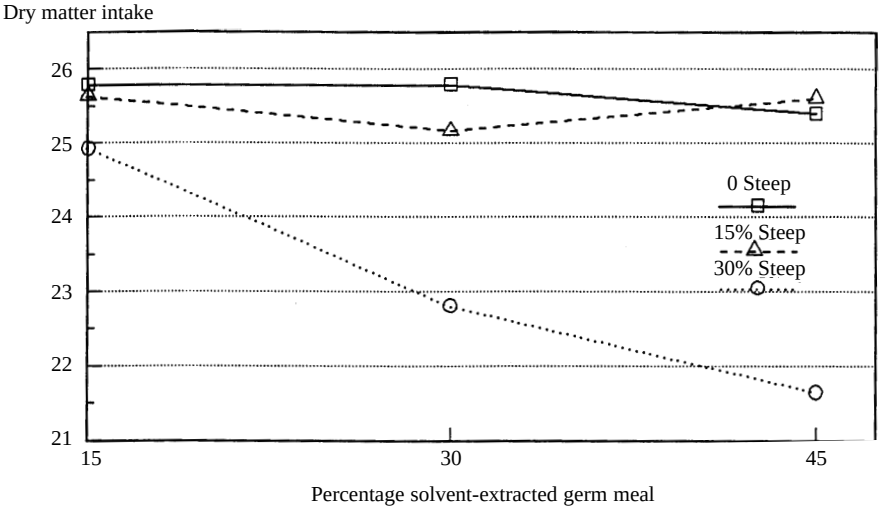

Figure 2. Solvent-extracted germ meal by steep liquor/distillers solubles level interaction exhibited for daily DM intake in Trial 2. A linear decrease in DM intake occurred as solvent-extracted germ meal concentration increased within the 30% steep liquor level (P<.05). Mean daily DM intake for the dry-rolled corn control treatment was 23.25 lb.

Table 4. Effect of corn byproduct blends on calf performance in Trial 3.

	Diet (% of DM)[a]								
Item	DRC	67%BR 33%ST	67%GM 33%ST	50%BR 50%ST	50%GM 50%ST	50%ST 25%BR 25%GM	50%ST 25%BR 25%GM + Fat	33%BR 33%GM 33%ST	33%BR 33%GM 33%ST + Fat
Daily gain, lb[b]	3.74	3.80	3.95	3.82	3.99	3.86	3.92	3.85	4.02
DM intake,lb/day[cd]	22.50	23.31	22.85	22.67	22.18	22.02	22.14	22.16	22.08
Feed/gain[def]	6.02	6.13	5.78	5.93	5.56	5.70	5.65	5.76	5.49
Quality grade[g]	18.5	18.7	18.7	18.9	18.5	18.7	18.8	18.2	18.4
Yield grade	2.3	2.6	2.6	2.6	2.4	2.5	2.6	2.1	2.6
Fat thickness, in	.46	.50	.53	.50	.47	.51	.54	.46	.50

[a]DRC = dry-rolled corn, BR = dry corn bran, ST = steep liquor/distillers solubles, GM = solvent-extracted germ meal, Fat = tallow.
[b]Linear BR vs GM level P=.01. DRC vs byproduct diets without tallow P=.10.
[c]Quadratic BR vs GM level P<.01.
[d]33% vs 50% ST P<.05.
[e]Linear BR vs GM level P<.01.
[f]Analyzed as gain/feed, the reciprocal of feed/gain.
[g]18 = high select, 19 = low choice.

Trial 3

Compared to the combined group of corn byproduct blends without added tallow, the DRC treatment tended to elicit a lower average daily gain (P=.10). However, neither DM intake nor feed-to-gain ratio was different when means for byproduct blends without tallow were pooled. Combining and contrasting treatments based on ST level (33 vs 50%) indicated a decrease in DM intake, as well as enhanced feed efficiency with increasing level of ST (Table 4). This analysis excluded the DRC treatment and those containing 3% added tallow. No byproduct blend by tallow interaction existed, therefore data were combined for the 50%ST,25%BR, 25%GM and 33%BR,33%GM,33%ST diets and contrasted with those containing added tallow. A significant increase in average daily gain was achieved when cattle consumed tallow (3% of DM) in addition to the BR, ST, GM combinations at 22.5% of dietary DM (P=.05). Feed-to-gain ratio also decreased within these combined treatments with tallow addition (P=.06).

To examine the influence of BR and GM level on calf performance, means were analyzed after combining these two ingredients across treatments into high (67 and 50%), medium (33 and 25%) and low (0%) BR and/or ST categories. A quadratic response was o bserved for DM intake as GM concentration moved from low to high levels (P<.01). Intake means for high, medium and low levels of GM were 22.5, 22.1 and 23.0 lb per day. Average daily gain and feed efficiency increased linearly for the low (3.81 lb, 6.03), medium (3.86 lb, 5.73) and high (3.97 lb, 5.67) levels of GM (P=.01, P<.01). These responses indicated diets containing GM may possess more energy than those with BR. Additionally, high intake obtained with high BR diets may have diminished efficiency.

Results of these trials demonstrate the value of corn byproducts for finishing cattle relative to DRC. However, both intake and feed efficiency were influenced by the composition of the BR, GM and ST blend. Consumption of BR diets tended to be greater than when GM was included at the same dietary level. Dry corn bran lacks the readily fermentable carbohydrates present in DRC, ST and GM; it provides lower dietary energy content while it simultaneously diminishes the incidence of acidosis and allows for heightened consumption. In Trial 2, GM alone numerically enhanced performance above the DRC diet. Conversely, in Trial 1, penfed cattle responded to GM at 9% of diet DM with means for intake and daily gain similar to those obtained with DRC. When comparing data from Trials 1 and 2, it is unclear whether GM as a single ingredient provides an improvement in performance over that exhibited by DRC alone.

When GM was combined with ST, the response in intake and daily gain was not consistent as ST level increased. Performance of cattle in Trial 1 did not appear diminished when ST was included at 19% of DM and blended with GM. In Trial 2, however, cattle performance declined between the 15 and 30% levels of ST when GM level reached 30 and 45%. Feeding GM with ST at lower dietary concentration in Trial 3 demonstrated a possible beneficial association between these two byproducts when they comprise a small portion of the DM.

Treatments including three-way combinations of BR, ST and GM elicited satisfactory intake and daily gain, indicating these three byproducts combined may serve as an alternative to feeding WCGF alone. Additions of tallow to these blends further enhanced performance and showed tallow can be combined with corn byproduct blends in small quantities without adversely effecting dietary characteristics.

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Lipid Sources in Finishing Diets for Yearling Steers

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Daily gain may be slightly improved when a corn-based finishing diet is supplemented with 1.12% lipid from Synergy, a processed soybean oil refining byproduct or from pork fat.

Summary

Adding Synergy[2] *to a corn-based finishing diet to provide 1.12% lipid did not significantly increase steer performance in this trial or in pooled results between this trial and one reported in 1995. However, numerical increases were observed in daily gain and feed dry matter intake for Synergy when compared to control values. Pooled results for additions of pork fat (white grease) to provide 1.12 or 2.24% lipid were intermediate to those for the control and Synergy treatments. Any performance benefit attributed to Synergy may be as much from its effect on dry matter intake as it is from nutrient addition.*

Introduction

Results of a yearling finishing trial with supplements of soybean oil refining byproduct and pork fat (white grease) were presented in the 1995 Nebraska Beef Report, pp. 22-24. The two sources of lipid were equally effective at improving daily gain and feed efficiency for a corn-based diet with corn silage as the source of roughage. Sources of fat are often added to finishing diets to increase energy density and improve feed efficiency. However, animal fats are difficult to handle, especially during cold weather, and storage tanks, piping and pumps must be heated so the fats can be handled as a liquid. Because of the equipment investment needed to handle animal fats, large quantities need to be fed to justify the cost. As a consequence, most animal fats are fed in large commercial feedlots. Oilseed lipids have an advantage, as they stay in a liquid state during cold weather, blending easier with liquid molasses based protein supplements. This advantage allows cattle feeders to increase energy density of diets by using oilseed lipids more conveniently with less expensive equipment.

A second finishing trial was initiated to study similar additions of Synergy liquid supplement or pork fat and lecithin, a plant phospholipid, to a corn-based diet with alfalfa hay as the source of roughage. The objective was to determine effects of these lipids on daily gain, feed efficiency and carcass characteristics in finishing yearling steers.

Procedure

For this trial, 216 crossbred steers weighing approximately 850 lb were purchased from one source. The steers had been fed together for the previous 120 days and were uniform in condition. The steers were randomly assigned to 18 pens and the pens randomly assigned (blocked within location) to six treatments. The supplemental treatments were additions of lipids to supply 1.12 or 2.24% lipid in diet dry matter as follows:

1) Control - dry protein supplement (58% crude protein).
2) Combination of control and Synergy supplements to supply 1.12% soy lipid from Synergy.
3) Control supplement plus 1.12% pork fat.
4) Control supplement and Synergy to supply 1.12% soy lipid

Table 1. Composition of finishing diets and calculated nutrient contents.

Treatments	Control	Synergy[a] 19/14	Control +1.12% Pork fat	Synergy +1.12% Pork fat	Control +2.24% Pork fat	Control +1.12% Lecithin +1.12% Pork fat
Ingredients, % of DM						
Corn	83.3	78.7	81.9	77.5	80.6	80.7
Alfalfa hay	10.0	10.0	10.0	10.0	10.0	10.0
Beef finisher 58%	6.7	4.2	6.9	4.4	6.7	7.1
Synergy 19/14		5.9		5.9		
Rumensin supplement		1.1		1.1		
Pork fat			1.12	1.12	2.24	1.12
Non-medicated supp 40%					0.5	
Lecithin						1.12
Calculated contents, % of DM						
Dry matter	86.8	84.6	87.0	84.7	87.1	87.2
Crude protein	13	13	13	13	13	13
Fat	3.9	5.0	5.0	6.1	6.0	5.7
Calcium	.83	.74	.85	.74	.87	.86
Phosphorus	.34	.38	.34	.37	.34	.34
Roughage	10	10	10	10	10	10
Rumensin, g/ton	30	30	30	30	30	30

[a]Synergy 19/14 is a patented processed product of Cargill, Inc., from soybean oil refining byproduct supplying 19% crude protein and 14% fat.

Table 2. Average chemical analysis of diets from bunk samples.

Treatments	Control	Synergy[a] 19/14	Control +1.12% Pork fat	Synergy +1.12% Pork fat	Control +2.24% Pork fat	Control +1.12% Lecithin +1.12% Pork fat
Composition, % of DM						
Dry matter	85.60	84.14	86.29	84.25	86.79	86.89
Crude protein	13.87	14.13	13.37	14.10	13.82	13.93
Crude fat	3.09	4.33	4.00	4.99	5.43	5.29
Acid detergent fiber	8.13	7.61	7.75	7.48	8.70	7.75
Calcium	0.89	0.86	0.90	0.81	0.87	0.87
Phosphorus	0.36	0.38	0.36	0.38	0.36	0.39

[a]Synergy 19/14 is a patented processed product of Cargill, Inc., from soybean oil refining byproduct supplying 19% crude protein and 14% fat.

plus 1.12% pork fat.

5) Control supplement plus 2.24% pork fat.
6) Control supplement plus 1.12% pork fat and 1.12% lecithin.

Upon arrival, cattle were processed with routine vaccinations, pouring for external parasites and implanting with Synovex S. The average of two weights on consecutive days was used as the initial weight. Individual weights were taken both after 56 days on feed and at the end of the trial. All weights were taken in the early morning before feeding. The live weights of the cattle taken prior to slaughter were used to calculate dressing percentage; however, the final finished weight was based on carcass weight divided by a common dressing percentage (.625).

Final finishing diets (shown in Table 1) contained Rumensin (30 g/ton of ration DM) and Tylan (9 g/ton of ration DM). Major minerals and protein levels were constant for all rations. The cattle were started on rations containing 50% roughage and were stepped up by decreasing roughage at 10% increments through three step-up rations at approximately 6-day intervals. The laboratory analysis of bunk samples averaged over the feeding period is shown in Table 2.

The cattle were slaughtered after 126 days on feed and liver abscess data and hot carcass weights were collected. After a 48 hour chill, the carcasses were evaluated for marbling, maturity, rib eye area, fat cover over the rib eye and percentage of kidney, heart and pelvic fat. Statistical analyses were conducted utilizing SAS-GLM procedure. The model statement included initial weight (as a covariate), treatment, replication and treatment by replication interaction. Treatment by replication interaction was used as the error term to test for treatment differences.

Four treatments were common between this trial and a similar one reported in the 1995 Nebraska Beef Report. These treatments were: control; Synergy to provide 1.12% lipid; pork fat to provide 1.12% lipid; and pork fat to provide 2.24% lipid. Diet energy levels, cattle types and days on feed were similar. Results were pooled for statistical analysis.

(Continued on next page)

Table 3. Cattle performance and carcass characteristics with two levels of lipids and one level of lecithin.

Treatments	Control	Synergy[a] 19/14	Control +1.12% Pork fat	Synergy +1.12% Pork fat	Control +2.24% Pork fat	Control +1.12% Lecithin +1.12% Pork fat	P Value
No. Cattle	36	36	36	36	35	36	
Pens/Treatments	3	3	3	3	3	3	
Performance							
Initial wt, lb (June 7)	852	855	852	844	863	865	CoVAR
Final wt, lb (Oct. 11)[b]	1260	1279	1267	1268	1277	1270	.58
126 day ADG, lb[b]	3.24	3.36	3.30	3.37	3.26	3.22	.58
Feed DM intake, lb	22.8	24.0	23.0	23.2	22.6	23.0	.57
Feed/gain ratio	7.05	7.15	6.98	6.94	6.94	7.16	.75
Carcass Characteristics							
Hot carcass wt, lb	788	800	792	793	798	794	.58
Dressing %[c]	62.8	63.2	63.0	63.2	63.2	63.1	.91
Fat cover, in	.52	.49	.54	.47	.50	.51	.86
Quality grade[d]	18.5	18.4	18.1	18.4	18.0	18.1	.48
Marbling[e]	5.21	5.19	5.08	5.31	5.06	5.09	.81
% Choice or above	68.6	66.7	54.3	62.9	60.6	55.9	
Rib eye area, sq in	12.7	12.8	12.6	13.1	13.1	12.3	.039
Yield grade[f]	3.27	3.33	3.42	3.25	3.26	3.33	.45
% Condemned livers	17.1	16.7	8.3	8.6	5.7	11.4	

[a]Synergy 19/14 is a patented processed product by Cargill, Inc., from soybean oil refining byproduct supplying 19% crude protein and 14% fat.
[b]Final live weight adjusted by dividing carcass weight by .625, a common dressing percentage.
[c]Dressing percent = hot carcass weight ÷ full live weight x .96
[d] Low Choice = 18, Ave. Choice = 19
[e]Small degree of marbling = 5, Modest = 6
[f]Yield grade evaluated by federal grader

Results

Supplemental treatments did not significantly effect daily gain, feed efficiency or carcass characteristics (Table 3). There was a trend for cattle supplemented with Synergy to consume slightly more feed and gain slightly more. Feed efficiency did not appear to be different among the treatments. Ration quality (absence of dust or fines) appeared to be higher for the rations containing Synergy and lowest for the control ration. When lecithin was added at 1.12% of the ration DM along with 1.12% pork fat, dry matter intake and steer performance were similar to those observed in the control steers.

Carcass dressing percent, fat cover, marbling, quality grade and yield grade were not affected by treatments. Percentage of condemned livers was not increased by lipid treatments over the control.

Four steers were removed from the overall analysis. One steer died unrelated to the treatment. Two other steers were more than two standard deviations below the average for daily gain and another steer experienced health problems and had sub-standard gains. As a consequence, one steer was removed from the control treatment, one from Synergy plus 1.12% pork fat treatment, one from control plus 2.24% pork fat treatment and one from the 1.12% pork fat plus 1.12% lecithin treatment.

Pooled results for the four treatments common between this trial and the similar 1995 trial are presented in Table 4. Non-significant increases in daily gain and feed dry matter intake are shown for Synergy over the control values. The 1.12% lipid addition to the diet from Synergy may not affect performance as much as it affects dry matter intake. The easy-flowing Synergy liquid supplement appeared to improve ration quality by reducing fines or dust, which could be the reason for any increased feed intake. These results suggest lipid from soybean oil refining byproduct is as effective as pork fat (white grease) for supporting performance of finishing steers.

Table 4. Pooled results for two finishing trials with Synergy and pork fat supplements.

	Control	Synergy 1.12% lipid	Pork fat 1.12% lipid	Pork fat 2.24% lipid	P Value
No. of pens	6	6	6	6	
No. of steers	71	71	71	71	
Initial wt, lb	822	823	821	825	
Final wt, lb[a]	1240	1264	1255	1255	.35
Daily gain, lb[a]	3.33	3.52	3.46	3.42	.35
Feed DM intake, lb	23.6	24.6	24.1	23.8	.47
Feed/gain ratio	6.30	6.32	6.24	6.28	.63

[a]Final live weight and daily gain calculated by dividing hot carcass weight by a common dressing percentage (62.5).

An Enzyme-Microbial Feed Product for Finishing Steers

Burt Weichenthal
Ivan Rush
Brad Van Pelt[1]

The MSE feed additive containing multiple enzymes, microbes and yeast appears to be competitive with Rumensin/Tylan for supporting an economical finishing performance in yearling steers.

Summary

Feeding MSE (multiple stabilized enzymes in an enzyme-microbial feed product) at the rate of 2 lb of product per ton of diet dry matter in two trials with finishing yearling steers, increased daily gain by an average of 6.9% over feeding Rumensin-Tylan at 29 g and 10 g per ton, respectively. Feed-to-gain ratio was improved by an average of 5.6% with MSE in the same comparison. Carcass measurements were similar, except for slight increases in hot carcass weight and dressing percent for cattle fed MSE. Percentages of liver abscesses were low and similar for both treatments.

Introduction

The 1996 Nebraska Beef Report (pp. 68-69) included results from a finishing trial using British crossbred yearling steers in which Rumensin-Tylan was compared to MSE, a feed product containing multiple stabilized enzymes plus four strains of bacteria (three Lactobacillus cultures and one of Bacillus subtilis), three strains of yeast (Saccharomyces cerevisiae) and three strains of fungi (two of Aspergillus oryzae and one of Aspergillus niger). Steers fed MSE gained about 10% faster and 7.5% more efficiently than those fed Rumensin-Tylan. Liver abscesses were similar for both treatments. These results suggested Rumensin-Tylan could be replaced by MSE, especially in situations such as organic beef production, without the use of antibiotics. A second trial was initiated to test the same comparison with large-framed yearling steers and a similar diet differing only

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[2]Synergy 19/14 supplement is a patented product of Cargill Molasses Liquid Products Division, Elk River, MN, and supplies 19% crude protein and 14% lipid from processed soybean oil refining byproduct.

in the replacement of 35% of the corn dry matter with ground, ensiled high-moisture corn.

Procedure

Charolais crossbred yearling steers were purchased in the spring for allotment to 12 pens of nine head each for six pens on each of two treatments: (1) Rumensin fed at 29 grams and Tylan at 10 grams per ton of diet dry matter, and (2) the enzyme-microbial feed product MSE fed at 2 lbs per ton of diet dry matter. Three step-up diets were used to reach the final diet, which on a dry matter basis included 53.6% dry rolled corn, 28.9% high-moisture corn, 10.0% corn silage and 7.5% protein-mineral-vitamin supplement including NPN and natural protein to provide 58% crude protein. Calculated nutrient contents of the diet dry matter were 12.5% crude protein, .65 Mcal NEg per lb, .77% calcium and .34% phosphorus.

The MSE was premixed at the rate of 2 lbs of MSE with 8 lbs of finely ground corn so that ten pounds of premix were added to the mixer truck after all other ingredients had been added. During the first 72 hours on feed, MSE was fed at 6 lbs of diet dry matter (three times higher than the long-term feeding rate). Rumensin was fed at 25 grams per ton of diet dry matter during the first three days, at 28 grams during the next step-up and at 29 grams thereafter. A pelleted protein supplement with and without Rumensin-Tylan was used in the study.

The large-framed, yearling Charolais crossbred steers, weighing about 812 pounds when started on trial on February 22, 1996, were purchased from two sources and were not implanted. The steers were fed once a day at levels allowing them to clean up most of the feed before the next feeding. The steers were slaughtered after 139 days on feed and carcasses were evaluated for dressing percentage, fat thickness, marbling, quality grade, rib eye area and yield grade.

One steer died during the test, apparently unrelated to treatment, and one bull was removed. Carcass measurements could not be taken on a few carcasses per treatment at the packing plant, but hot carcass weights were available on 51 carcasses per treatment and measurements for fat thickness and rib eye area were available for 48 carcasses per treatment. Final weights and daily gains were calculated for 51 steers per treatment by dividing hot carcass weights by a common dressing percent (62). Daily gains and carcass measurements for individual steers were analyzed by the general linear model in SAS. Feed intake and feed conversion means were analyzed by SAS with pen as the experimental unit.

Table 1. Rumensin-Tylan vs MSE[a] for large-framed finishing steers, 1996 trial.

	Rumensin-Tylan	MSE
No. of pens	6	6
No. of steers	51	51
Initial weight, lb	810	814
Daily gain, 84d, lb	4.04	4.19
Final weight, lb[b]	1284	1305
Daily gain, 139d, lb[b]	3.41	3.54
Feed DM intake, lb	21.82	21.91
Feed/gain	6.41	6.19
Hot carcass weight, lb	796	809
Dressing percent	63.6	64.0
Fat thickness, in	.31	.29
Rib eye area, sq in	14.3[c]	14.6[d]
Rib eye area, sq in per cwt of carcass	1.8	1.8
Marbling score[e]	5.1	5.0
Quality grade[f]	18.2	18.0
Percent Choice	51.0	45.3
Yield grade	2.1	1.9
Liver abscesses, %	13.2	11.3

[a]MSE = Multiple Stabilized Enzymes, an enzyme-microbial feed product of Natur's Way, Inc., Horton, KS.
[b]Final weight and daily gain were calculated by dividing hot carcass weight by a common dressing % (62).
[cd]Means differ (P < .06).
[e]Marbling scores: Small begins at 5.0, Modest at 6.0.
[f]Quality grade scores: Choice- begins at 18.0.

Results

Average daily gains for Rumensin-Tylan and MSE treatments were 4.04 and 4.19 lb at 84 days, and 3.41 and 3.54 lb (P = .42) at 139 days on feed, respectively (Table 1). Means for dry matter intake were similar for both treatments. At 84 days, a power outage during hot weather caused the cattle to be without water, which reduced feed intake. However, both treatment groups came back on full feed in a few days. Final feed to gain ratios were 6.41 and 6.19 for Rumensin-Tylan and MSE, respectively, a difference not statistically significant (P = .24).

Means for carcass measurements were similar between treatments. Numerical differences in hot carcass weight, dressing percent, marbling score and yield grade, were not statistically significant. Rib eye area was larger (P < .06) with MSE, but rib eye area per cwt of carcass was the same. Percentages of liver abscesses were 13.2 and 11.3% for Rumensin-Tylan and MSE, respectively, which were neither excessive nor unusual for a high-grain diet in which the only roughage component was in the corn silage fed at 10% of diet dry matter.

Since the 1995 and 1996 trials were similar in design, and there were no interactions between years, results were pooled (Table 2) for statistical analysis. Pooled means for 12 pens on each treatment resulted in improvements for MSE ($P \leq .1$) in final weight (adjusted to a common 62% carcass dress), hot carcass weight, daily gain and feed conversion. Dressing percent was higher for MSE (P < .05). Feeding MSE at the rate of 2 lb of product per ton of diet dry matter increased daily gain by an average of 6.9% over the feeding of Rumensin-Tylan at 29 g and 10 g per ton, respectively. Feed-to-gain ratio was

(Continued on next page)

Table 2. Rumensin-Tylan vs MSE[a] for finishing yearling steers, 1995 and 1996 trials pooled.

	Rumensin-Tylan	MSE
No. of pens	12	12
No. of steers	96	94
Initial weight, lb	835	838
Final weight, lb[b]	1267	1298
Daily gain, 130 d, lb[b]	3.32[c]	3.55[d]
Feed DM intake, lb	22.36	22.62
Feed/gain ratio	6.77[c]	6.39[d]
Hot carcass weight, lb	785[c]	805[d]
Dressing percent	63.1[e]	63.7[f]
Fat thickness, in	.42	.41
Rib eye area, sq in	13.6[e]	13.9[f]
Rib eye area, sq in per cwt of carcass	1.7	1.7
Marbling score[g]	5.3	5.2
Quality grade[h]	18.5	18.3
Percent Choice	63.6	58.3
Yield grade	2.5	2.4

[a]MSE = Multiple Stabilized Enzymes, an enzyme-microbial feed product of Natur's Way, Inc., Horton, KS.
[b]Final weight and daily gain were calculated by dividing hot carcass weight by a common dressing % (62).
[cd]Means differ (P ≤ .1).
[ef]Means differ (P < .05).
[g]Marbling scores: Small begins at 5.0, Modest at 6.0.
[h]Quality grade scores: Choice- begins at 18.0.

improved by an average of 5.6% when MSE was fed. Carcass measurements were similar except for increases in hot carcass weight (P < .1) and dressing percent (P < .05) with MSE. Although the mechanism for any response to MSE remains to be defined, improved feed utilization is suggested during ruminal digestion. The costs of the two feed additive treatments were similar, so the feeding of MSE appears to be competitive with the feeding of Rumensin-Tylan to finishing yearling steers. These results may also be useful for producers of organic beef where the routine feeding of antibiotics is avoided.

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Lime Filtrate as a Calcium Source for Finishing Cattle

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Lime filtrate can effectively replace limestone as a source of calcium in beef finishing diets. However, inclusion of excess calcium may depress animal performance.

Summary

Finishing diets containing wet corn gluten feed were fed to 128 yearling steers to evaluate inclusion of lime filtrate as the source of supplemental calcium. Lime filtrate supplied 0, 50, 100 and 150% of the base calcium level of .70%, with limestone supplying the remainder. While dry matter intake was reduced for the 100% level of calcium from lime filtrate (P<.10), average daily gain and feed efficiency were not different from the limestone control. The 150% level of calcium from lime filtrate did reduce average daily gain and feed efficiency (P<.10).

Introduction

The wet milling industry produces byproducts primarily used in livestock feeding operations and feed manufacturing. Steep liquor and distillers solubles are added to corn bran to manufacture wet corn gluten feed. Although wet gluten feed is high (.5 to .8%) in phosphorus, it is very low in calcium. Supplemental calcium, usually in the form of limestone, must be added to cattle diets including wet gluten feed to ensure adequate amounts of dietary calcium.

The corn milling process, on the other hand, utilizes large quantities of water treated with hydrated lime. This high-calcium residual lime filtrate is currently disposed of in landfills or applied to fields for pH adjustment. Addition of lime filtrate to wet corn gluten feed may replace limestone as the source of supplemental calcium in finishing diets.

The objectives of this trial were to evaluate lime filtrate as a calcium source for cattle finished on wet corn gluten feed and to determine the optimal inclusion level of lime filtrate in cattle finishing diets.

Procedure

A finishing trial was conducted using 128 yearling crossbred steers (850 lb) to evaluate lime filtrate as a source of calcium relative to limestone. Steers

Table 1. Lime filtrate as a calcium source, ration composition

	% Supplemental Ca from lime filtrate			
Ingredient, % diet DM	0	50	100	150
Corn gluten feed	45.00	45.00	45.00	45.00
Dry rolled corn	43.07	43.00	42.95	41.95
Alfalfa hay	7.50	7.50	7.50	7.50
Supplement[a]	3.00	3.00	3.00	3.00
Limestone	1.43	.72	—	—
Lime filtrate	—	.78	1.55	2.55
% Dietary Ca	.70	.70	.70	1.05

[a]Contains corn, salt, tallow, trace minerals, vitamins, Rumensin and Tylan.

Table 2. Animal performance response to inclusion of lime filtrate.

	% Supplemental Ca from lime filtrate				
Item	0	50	100	150	SE
Initial weight, lbs	849	850	852	852	1.7
Final weight[a], lbs	1268	1259	1264	1245	12.5
Average daily gain, lbs	3.41	3.33	3.37	3.19	.10
Dry matter intake, lbs	26.75[b]	25.93[bc]	25.51[c]	25.70[bc]	.47
Feed/gain[d]	7.81[bc]	7.75[bc]	7.58[b]	8.06[c]	.21
Backfat thickness, in.	.55[b]	.54[b]	.48[c]	.47[c]	.02
Quality grade[e]	19.28[b]	19.25[b]	19.00[bc]	18.88[c]	.12
Yield grade	2.66	2.53	2.53	2.59	.12

[a]Hot carcass weight divided by a common dressing percentage (62%).
[b,c]Values within a row with unlike superscripts differ (P<.10).
[d]Feed/gain analyzed as gain/feed. Feed/gain is the reciprocal of gain/feed.
[e]Quality grade of 20=average Choice, 19=low Choice, 18=high Select.

were blocked by weight into four replications and assigned randomly, within a block, to one of four pens (8 head/pen). Each pen within a block was assigned randomly to one of four dietary treatments based upon the inclusion level of lime filtrate. Lime filtrate supplied 0, 50, 100 and 150% of the dietary calcium level of .70%, with limestone supplying the remainder (Table 1). Although the dietary calcium requirement was .36% (850 lb steer gaining 3.4 lb/day at 26 lb DMI; 1996 Nutrient Requirements for Beef Cattle Computer Model), the .70% calcium level was used to maintain a calcium:phosphorus ratio greater than 1.2. Previous research has shown improved feed efficiency when .70% calcium was fed.

The dietary phosphorus content, .53%, was greater than the requirement of .18% (850 lb steer gaining 3.4 lb/day at 26 lb DMI; 1996 Nutrient Requirements for Beef Cattle Computer Model) due to the high level of phosphorus in wet corn gluten feed. Diets were formulated to contain a minimum of 12% crude protein, 6.8% degradable protein, .6% K, 25 g/ton Rumensin and 10 g/ton Tylan. Steers were implanted with Revalor-S at the initiation of the experiment. Initial weights were the average of weights collected on two consecutive days (October 14th and 15th, 1996) following a four-day period of limited intake to reduce weight variation due to fill. Final weights were calculated following slaughter by dividing hot carcass weight by 62% (common dressing percentage). Average daily gain, dry matter intake and feed/gain were performance criteria evaluated. Additionally, carcass criteria evaluated included fat thickness at the 12th rib, quality grade and yield grade.

Results

Two replications of steers were fed for 116 days; the remaining two replications were fed for 129 days. Inclusion of lime filtrate to supply 100% of the supplemental calcium reduced dry matter intake relative to limestone (P<.10). This did not appear to be a problem associated with palatability since intake was not significantly reduced for the 150% level of calcium from lime filtrate. More importantly, the 50 and 100% levels of calcium from lime filtrate were not detrimental to average daily gain or feed efficiency (Table 2). Actually, a numerical improvement in feed efficiency occurred when lime filtrate was the sole source of additional calcium.

Feeding lime filtrate to provide more than .70% calcium was detrimental; animal gains tended to be reduced when lime filtrate was fed to supply 150% of the .70% calcium level. Likewise, the 150% level of calcium from lime filtrate significantly reduced efficiency (P<.10). Quality grade was also significantly reduced when the 150% level was fed (P<.10). This difference in quality grade may be due to the numerical difference in final weight and average daily gain. Backfat thickness, measured between the 12th and 13th rib, was significantly reduced when the 100% and 150% levels of calcium from lime filtrate were fed (P<.10), although level of calcium from lime filtrate did not effect yield grade.

Lime filtrate appears to be equal to limestone as a calcium source for finishing cattle, as it supported animal performance equivalent to limestone when fed to replace 50% and 100% of the supplemental calcium. However, inclusion of lime filtrate in excess of the .70% calcium level depressed animal performance. This is consistent with previous research.

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Extended Grazing and Byproduct Diets in Beef Growing Finishing Systems

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Maximizing amount of gain on forages reduced costs of production and slaughter breakevens in growing-finishing beef systems.

Summary

Two experiments evaluated methods of reducing costs of finished beef. The first experiment, used lambs as a model for cattle. A dry rolled corn diet served as a control and two byproduct diets: 1) corn gluten feed; or 2) gluten feed plus wheat midds, were supplemented with three levels of tallow. Byproduct diets gave feed efficiencies nearly equal to corn and efficiencies increased with tallow supplementation . In the second experiment, 128 steers were used in grazing systems including smooth brome, warm-season grasses, oats and cornstalks and finished on corn or byproduct diets. High forage gains reduced costs and slaughter breakevens.

Introduction

Forages are an important part of beef production but often are not used to the best extent. We have found (1995 Beef Cattle Report, pp 34) maximizing the amount of gain on forage before entering the feedlot reduces costs of production. There are, however, a number of alternative ways to achieve maximum gain including high rates of forage gains and longer time periods on forage.

For one, cattle can be finished on byproducts (1995 Beef cattle Report, pp 34). Byproducts are generally priced cheaper than corn and are not well utilized by monogastrics. Our objectives in this study were to minimize costs of beef production by increasing forage gains and optimizing byproduct diets.

Procedure

Experiment 1.

Sixty-three cross-bred lambs were randomly assigned to one of seven treatments according to a $2 \times 3 + 1$ factorial design (Table 1). There were two byproduct diets: one, a wet corn gluten feed which is a blend of 1/3 steep liquor/distiller solubles and 2/3 corn bran; and the second diet, where one-half of the corn bran was replaced with wheat midds. Steep liquor/distiller solubles remained constant across all diets. Tallow was added to each of the byproduct diets at concentrations of 0, 4 and 8% replacing either bran or bran and midds. Corn gluten meal and blood meal were added to the byproduct diets to supply equal undegradable intake protein to the dry rolled control. The lambs were individually fed for 84 days. They were "stepped up" by feeding 2% of body weight initially and increasing intake by .2% body weight each day until ad libitum intake was achieved. Lambs were weighed three times at the initiation and conclusion of the trial. Economic analyses used prices from Feedstuffs magazine for wheat midds from July 18, 1994 to November 6, 1995 which averaged 67% the price of corn grain. Other prices used were actual market prices.

Experiment 2.

One-hundred-twenty eight British-breed steer calves were wintered on cornstalks and hay. On May 5, 1996, they were randomly allotted to 16 groups and eight treatments (Table 2). The calves averaged 579 lb on May 5 when they were implanted with Compudose, fly tagged and placed on pasture. The cattle were fed a common diet at 2% of body weight five days before being weighed on two consecutive days at the beginning and the end of the grazing periods. On June 13,1996, cattle from the two treatments were moved to warm-season grass and returned to brome on August 23, 1996.

For fall grazing, the appropriate cattle were moved to oats on September 18, 1996 and returned to brome on October 22, 1996. The oats had been seeded in wheat stubble. The appropriate cattle were moved to cornstalks on September 30, 1996. The cornstalks were available at that time because the grain had

Table 1. Diet composition as a % of DM.

	1	2	3	4	5	6	7
Dry rolled corn	87.5						
Corn bran		60.71	56.66	52.66	30.02	28.01	26.02
Wheat midds					29.36	27.40	25.44
Steep liquor		29.11	29.12	29.12	29.27	29.26	29.26
Alfalfa hay	5.01	5.09	5.09	5.08	5.11	5.12	5.11
Liquid 32	3.75						
Control supplement[a]	3.81						
Treatment supplement[b]		3.89	3.89	3.89	3.91	3.91	3.90
Fat (tallow)			4.05	8.06		4.06	8.10
Limestone		1.20	1.19	1.19	2.32	2.24	2.16

[a]Control supplement: fine ground corn (54.95%), limestone (24.09%), salt (7.26%), potassium chloride (6.56%), ammonium Sulfate (6.05%), sheep trace minerals(.73%) and vitamins (.36%).
[b]Treatment supplement: corn gluten meal (72.36%), blood meal (13.42%), salt (7.17%), ammonium sulfate (5.97%), sheep trace mineral(.72%) and vitamins (.36%).

Table 2. Treatment description and days in summer, fall and finishing phases.

Item Treatment:	1	2	3	4	5	6	7	8
Summer								
Bromegrass	130[a]	130	59	59	130	130	130	130
Warm season[b]			71	71				
Fall								
Bromegrass	18	47	18	47	18	47	18	18
Oats		35		35		35		
Cornstalks	64		64		64		105	105
Finishing								
Dry rolled corn[c]	94	94					86	
All byproducts[d]			94	94	94	94		86

[a]Days allowed to forage or finishing diet
[b]Composed of the following species: big bluestem (*Andropogon gerardii),* indian grass *(Sorghastrum nnutans),* sideoats grama *(Bouteloua curtipendula),* little bluestem (*Schizachyrium scoparium*) and switchgrass (*Panicum virgatum*).
[c]Dry-rolled corn 85.46%, alfalfa 7.5%, molasses 5.6% and 1.98% supplement (dry-rolled corn .52%, limestone 1.40%, salt .3%, tallow .1%, potassium chloride .146%, Rumensin .0165%, and Tylan .011%)
[d]Wet corn gluten feed 60%, wheat midds 30%, alfalfa 7.5% and 2.5% supplement (dry-rolled corn .67%, limestone 1.35%, salt .3%, tallow .1%, beef trace mineral .02%, Rumensin .0165%, Tylan .011%, vitamin premix .01%, cuO .007% and thiamin 006%).

Table 3. Lamb performance and economical analyses by treatment.

Treatment	ADG[ab]	DMI[b]	Gain/ Feed	Feed/ Gain	Cost/ 100 lb feed	Cost/ 100 lb gain
Dry rolled corn	0.48	2.44	0.19	5.15	$6.45	$33.24
Corn bran[c], 0 %fat	0.48	2.88	0.17	5.92	5.43	32.12
Corn bran, 4 %fat	0.64	3.04	0.21	4.73	5.93	28.02
Corn bran, 8%fat	0.62	2.68	0.23	4.41	6.43	28.37
Wheat midds[c], 0 % fat	0.57	2.97	0.19	5.30	5.04	26.70
Wheat midds, 4 % fat	0.59	2.97	0.20	4.94	5.57	27.57
Wheat midds, 8 % fat	0.64	2.84	0.22	4.53	6.10	27.66

[a]Linear effect for fat addition (P<.10).
[b]Quadratic effect for fat addition (P<.10)
[c]No substitution effect among byproducts (P>.05).

been harvested and stored as high-moisture grain. On December 3, 1996, the early removal treatments were moved to the feedlot for finishing. Late-removal cattle were moved to fresh cornstalks for grazing until January 13, 1997. Cattle were finished on a dry rolled corn (DRC) diet or a byproduct diet (Table 2). All cattle were implanted with Revalor S upon entry in the feedlot. The early removal cattle were fed for 94 days; the late removal for 86 days. Carcass weights at slaughter divided by .62 (common dressing percentage) were used as final weights. Yield and quality grades, fat thickness, percentage choice and ribeye area were obtained at the slaughter plant.

Results

Experiment 1.

Lambs on the byproducts diets without added fat gained as rapidly as did those on DRC (Table 3). Fat content of the DRC diet was slightly higher than the byproduct diets. With 8% fat additions, byproduct diets had total fat contents of 12 to 12.6%. Dry matter intakes were higher on the byproduct diets than on the DRC diet. Feed conversion was slightly poorer for the byproduct diets without fat than for the DRC diet. Fat addition linearly increased gains (P<.10) and decreased feed conversions (P<.05). Corn bran and wheat midds had equal feeding values.

When compared to DRC, feed costs were reduced when byproducts were included, however, fat addition increased costs. Costs of gain were reduced by byproduct feeding.

Experiment 2.

Treatment combinations and grazing days are shown in Table 2. Summer rates of gain were typical for smooth brome (1.30 lb/day; Table 4). Rotation of cattle to warm-season grasses improved gain to 1.97 lb/day (P<.01). Fall grazing was a combination of brome regrowth and oats or cornstalks. Early removal steers, which grazed only brome in the summer, averaged 1.86 lb/day gain in the fall. Those also on warm-season grass in the summer gained 1.28 lb/day in the fall.

Early removal cattle gained 1.97 lb/day when grazing oats and brome, versus 1.36 lb/day for those grazing cornstalks and brome (P<.01). While forage quality and cattle performance were excellent for the oats, carrying capacity was poor . Cornstalks did not provide previously obtained animal performance (1996 Nebraska Beef Report, pp 48-51 and 1997 Nebraska Beef Report, pp 56-59). Cornstalk quality is variable and heavily influenced by the amount of dropped ears. While harvesting corn early for high-moisture corn provides earlier grazing, it is likely there is less corn on the ground available for cattle.

Cattle grazing oats in the fall and gaining more weight than those on cornstalks also gained more weight in the feedlot (3.04 vs 2.66) and had better feed conversion (9.11 vs 10.83). The extra weight gained in the fall was maintained and actually enhanced feedlot performance.

Cattle fed the byproduct diet gained less (2.78 vs 3.51 lb/day) and had poorer feed conversions (10.34 vs 7.95; Table 4) than cattle fed the DRC diet. It is unclear why the cattle performed poorer on the byproduct diet when the lambs performed equally well on byproducts versus DRC.

Carcass data were similar across treatments. Cattle had .32 to .44 inches

(Continued on next page)

Table 4. Total performance for steers in different growing-finishing combinations.

Removal:	Early (12/1/96)						Late (1/13/97)	
Item	BG[a] CS DRC 1	BG OATS DRC 2	BG-WS CS BYP 3	BG-WS OATS BYP 4	BG CS BYP 5	BG OATS BYP 6	BG CS DRC 7	BG CS BYP 8
Weight, lb								
May 5	576	579	578	578	579	579	578	581
Sept. 12	750	758	830	837	731	749	758	737
Dec. 1	876	934	898	979	873	916		
Jan. 13							917	905
Final	1173^{bf}	1258^{c}	1129^{e}	1236^{cd}	1094^{e}	1193^{bd}	1255^{c}	1203^{bd}
Daily Gain, lb								
Summer	1.33^{bc}	1.39^{c}	1.94^{d}	2.00^{d}	1.17^{b}	1.31^{bc}	1.38^{bc}	1.20^{bc}
Fall	1.53^{bc}	2.15^{d}	0.83^{f}	1.73^{c}	1.72^{c}	2.04^{d}	1.30^{e}	1.37^{bc}
Total	1.43^{b}	1.77^{ce}	1.39^{bd}	1.86^{e}	1.45^{b}	1.68^{c}	1.34^{bd}	1.28^{d}
Finishing performance								
ADG, lb.	3.16^{bc}	3.44^{c}	2.45^{f}	2.73^{ef}	2.36^{f}	2.94^{bc}	3.92^{d}	3.46^{c}
DMI, lb/d	25.8^{ab}	27.1^{bc}	25.8^{c}	27.0^{d}	27.3^{d}	26.1^{b}	28.7^{f}	28.2^{e}
Feed/Gain	8.40^{b}	8.04^{b}	11.15^{d}	10.19^{cd}	12.95^{e}	9.09^{bc}	7.43^{b}	8.35^{b}
DOF[f]	93	93	93	93	93	93	86	86
Carcass data								
Back fat, in	.39^{bcd}	.40^{bd}	.32^{cd}	.44^{b}	.37^{cd}	.38^{bcd}	.39^{bd}	.40^{bd}
Ribeye, sq in	13.22^{b}	13.39^{b}	13.07^{bd}	13.08^{bd}	12.46^{bd}	13.39^{b}	14.20^{c}	13.74^{bc}
Percent choice	37.5	77.3	31.3	50.0	37.5	43.8	68.8	37.5
Yield grade	2.13^{bc}	2.46^{cd}	2.06^{b}	2.69^{d}	2.25^{bc}	2.31^{bc}	2.25^{bc}	2.44^{cd}

[a]BG=smooth brome continuous, BG-WS=smooth brome rotation with warm season, OATS=oats pasture, CS=cornstalks, DRC=dry-rolled corn and BYP=byproduct.
[b,c,d,e,f]Means with unlike superscripts differ (P<.05)
[g]Days on feed.

Table 5. Economical analyses by treatment for steer in different growing-finishing combinations.

Removal:	Early (12/1/96)						Late (1/13/97)	
Item	BG[a] CS DRC 1	BG OATS DRC 2	BG-WS CS BYP 3	BG-WS OATS BYP 4	BG CS BYP 5	BG OATS BYP 6	BG CS DRC 7	BG CS BYP 8
Steer cost, $[b]	478.81	479.05	479.74	479.50	480.20	480.51	480.08	482.52
Interest[c]	36.13	36.15	36.20	36.18	36.23	36.26	40.13	40.33
Health[d]	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00
Summer & fall costs, $								
Grazing[e]	59.48	86.10	59.48	86.10	59.48	86.10	64.40	64.40
Supplement[f]	10.24		10.24		10.24		16.8	16.8
Finishing costs,								
Yardage[g]	28.2	28.2	28.2	28.2	28.2	28.2	25.8	25.8
Feed[h]	123.01	129.10	103.83	108.85	109.8	105.0	125.71	104.42
Total costs, $[i]	764.51^{jkl}	789.04^{m}	747.35^{j}	768.91^{kl}	753.94^{jk}	766.10^{jkl}	783.27^{lm}	764.25^{jkl}
Final weight, lb[p]	1173^{jh}	1258^{k}	1129^{mn}	1236^{kl}	1094^{m}	1193^{jl}	1255^{k}	1203^{jl}
Slaughter Breakeven, $/100 lb[a]	65.71^{jl}	62.91^{jk}	66.45^{l}	62.48^{k}	69.27^{m}	64.33^{jkl}	62.59^{k}	63.63^{jk}

[a]BG=smooth brome continuous, BG-WS=smooth brome rotation with warm season, OATS=oats pasture, CS= cornstalks, DRC= dry-rolled corn and BYP=byproduct.
[b]Initial weight × $83/100 lb.
[c]9% Interest rate=Steer cost × (days owned × 9% annual interest)/365 d.
[d]Health costs=implants, fly tags, antibiotics, etc.
[e]Bromegrass=$.35/hd/day, warm season $.35/hd/day, oats $.69/hd/d, cornstalks $.12/hd/day.
[f]Supplement=$.16/hd/day during fall on cornstalks.
[g]Yardage=$.30/hd/day.
[h]Feed=Dry-rolled corn $.0489/hd/d, and all-byproduct $.0413/hd/day. Plus 9% interest for half the feed.
[i]Includes a 2% death loss.
[j,k,l,m,n,o]Means with unlike superscripts differ (P<.05).
[p]Calculated from carcass weight ÷ .62.
[q]Calculated with last 5 year average corn price of $2.36/bu.

of fat cover and yield grades 2.06 to 2.69. These are below industry averages. The cattle were finished with minimal time in feedlot, however, some of the cattle were produced with no grain feeding.

Dry-rolled corn diets produced lower slaughter breakevens than byproduct diets ($62.73/cwt vs $65.23) even though the cost of the byproduct diets was less (Table 5). This resulted from poorer feed efficiency from the byproduct diets. Additional fat in the diet might have been economical, based on the improved feed efficiencies in the lamb experiment.

Slaughter breakevens averaged less for cattle grazing oats compared to those grazing cornstalks ($63.24 vs $65.53/cwt) even though grazing oats was more expensive. The good gains on oats which carried through the feedlot phase increased carcass weights and reduced the breakevens. Grazing warm-season grass during the summer reduced breakevens, compared to grazing bromegrass alone ($64.46 vs $65.55/cwt). Extra gain from late grazing reduced breakevens compared to similar treatments removed in November ($63.11 vs $67.14/cwt). Lowest breakevens included oats grazing in early fall or late removal from cornstalks in January and dry-rolled corn diets for finishing.

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Effect of Winter Gain on Summer Rate of Gain and Finishing Performance of Yearling Steers

Dale Downs
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Steers wintered at 1.7 lb/day maintained approximately 80% of the weight advantage over steers wintered at .7 lb/day during summer grazing, justifying a rate of winter gain greater than .7 lb/day.

Summary

The effect of winter rate of gain on subsequent grazing and finishing performance was evaluated using 80 medium-framed steers. During the winter period, steers were fed to achieve gains of approximately .7 (low gain; 40 head) or 1.7 lb/day (high gain; 40 head). Warm-season Sandhills range was grazed by 20 low-gain and 20 high-gain steers, while the other 40 grazed bromegrass pasture from May to September. Both low- and high-gain cattle grazing brome pasture gained slower than those grazing sandhills range. During summer grazing, low-gain cattle gained faster than high-gain cattle, but compensated for only 19.9% (sandhills) and 18.7% (brome) of the weight deficit following the low-gain winter treatment.

Introduction

In Nebraska, management of medium-framed yearling steers from weaning to slaughter commonly consists of a winter and summer growing period followed by a relatively short finishing. These three phases have been found to be interactive relative to effects of previous nutrition on gain and efficiency in subsequent phases. That is, cattle subjected to nutritional restriction normally exhibit compensatory growth during subsequent periods of higher nutrient intake. Due to this response, accelerated rates (1.75-2.75 lbs/day) of winter gain may not translate into either heavier cattle at the end of summer grazing or fewer days in the feedlot. Consequently, harvested feeds or commercial supplements used to elicit higher winter gains may not be economical when considering the entire system. The potential exists to lower feed input costs during the winter and allow for compensatory gain during summer grazing. However, the optimum rate of winter gain in yearling systems remains an elusive and important question.

In Nebraska, yearlings are commonly grazed in the summer for 90 or more days during the grazing season before being placed in the feedlot. To avoid extra cost of ownership, if may be beneficial to remove cattle from grass earlier if gains are declining. To assist decision making of grazing season length, live weight-gain patterns of yearlings grazing various forages would be a useful tool. These growth patterns, however, may vary with previous nutrition and forage quality, further emphasizing the importance of this information to the yearling producer.

The objectives of this research were to evaluate the effect of winter gain on both summer rate of gain and finishing performance and to describe summer live weight gain patterns of grazing yearling steers.

Procedure

Eighty medium-framed, British-breed steers (497 lb) were used in a 2 x 2 factorial treatment arrangement with rate of winter gain and summer grazing forage type (location) as factors. Forty steers were assigned randomly to a low rate and 40 to a high rate of winter gain (approximately .7 and 1.7 lb/day, respectively). Following the winter period, 20 from each group were assigned to graze warm-season range in

(Continued on next page)

the Nebraska Sandhills or bromegrass pasture in Eastern Nebraska.

During the 163-day winter period, steers first grazed cornstalks, followed by the feeding of bromegrass hay and corn gluten feed to achieve desired winter gains. Steers were implanted with Compudose before summer grazing. On May 6, steers were placed on summer range/pasture and grazed until September 6. Steers in the Nebraska Sandhills grazed primarily warm-season pasture dominated by little bluestem, prairie sandreed, sand bluestem, blue grama and switchgrass. Steers assigned to Eastern Nebraska grazed smooth bromegrass. All animals were allowed access to a trace mineralized salt block throughout the winter and summer periods. Using ruminally fistulated steers, diet samples were taken at both locations throughout the summer grazing season and analyzed for CP and digestibility. Initial and final weights for the winter and summer phases were determined using the average of weights taken on two consecutive days following a five-day limit feeding period.

In order to describe live weight gain patterns during summer grazing, an automatic scale system was used to weigh individual steers each time they watered. If steers were weighed more than once daily, the minimum individual weights were used to calculate a daily mean for each treatment group.

Following removal from pasture, steers were implanted with Revalor and finished (10 head/pen) on a dry-rolled corn and corn gluten feed based diet (7.5% roughage) until an estimated .5 inch fat thickness was reached. Final weights were calculated using hot carcass weights assuming a common dressing percentage (62%). Liver abscess scores and hot carcass weights were taken at slaughter and fat thickness at the 12th rib, quality grades and yield grades were recorded following a 48-hour chill.

Results

Cattle on both the high- and low-gain winter treatments grazing brome pasture gained slower ($P < .05$) than those grazing sandhills range (Table 1). At both locations, steers wintered at a low rate gained faster ($P < .05$) than cattle on the high-winter gain treatment, exhibiting a degree of compensatory growth. The higher summer gains allowed steers to compensate for 19.9% (sandhills) and 18.7% (brome) of the weight deficit resulting from the low-gain winter treatment.

Figure 1 shows summer live weight gain patterns of steers grazing Sandhills range from the low- and high-gain winter treatments. Figure 2 shows weight gain patterns of steers grazing bromegrass pasture. Gains of cattle on sandhills range appeared to be linear or constant throughout the grazing season. In contrast, cattle grazing bromegrass appeared to gain rapidly from May to late June and leveled off for the remainder of the season. Steers on the low- and

Table 1. Steer performance for winter, summer and finishing periods.

	Sandhills Range		Bromegrass Pasture	
	Winter Gain			
Item	Low	High	Low	High
Winter				
Days	163	163	163	163
ADG, lb/d	.70[a]	1.67[b]	.68[a]	1.68[b]
Final weight, lb	611[a]	769[b]	608[a]	771[b]
Summer				
Days	123	123	123	123
ADG, lb/d	1.92[a]	1.66[b]	.73[c]	.48[d]
Final weight, lb	846[a]	973[b]	697[c]	830[a]
Finishing				
Days	99	71	124	99
ADG, lb/d	4.17[a]	4.57[ab]	4.48[a]	5.03[b]
DMI, lb/d	28.8[a]	31.3[ab]	28.6[a]	31.7[b]
Feed/gain	6.91[a]	6.84[a]	6.40[b]	6.31[b]
Final weight[e], lb	1262[ab]	1309[ab]	1249[a]	1323[b]
Yield grade	2.84[a]	2.37[b]	2.80[a]	2.95[c]
Fat thickness, in	.51[ab]	.44[a]	.48[ab]	.53[b]
Percentage of choice	90	58	100	79

[a,b,c,d]Means with unlike superscripts within a row differ ($P < .05$).
[e]Based on hot carcass weight adjusted to a common dressing percentage (62%).

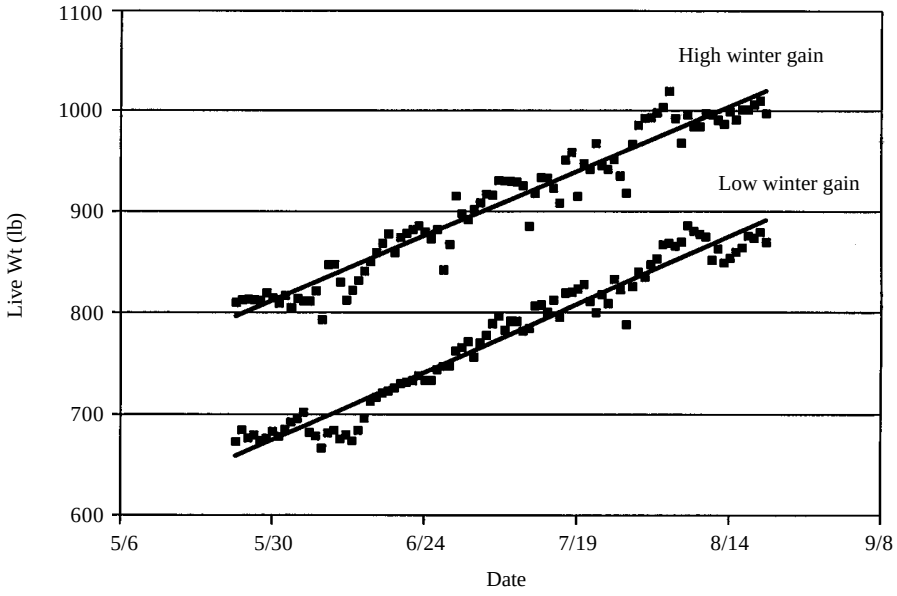

Figure 1. Summer weight gain patterns of steers grazing sandhills range.

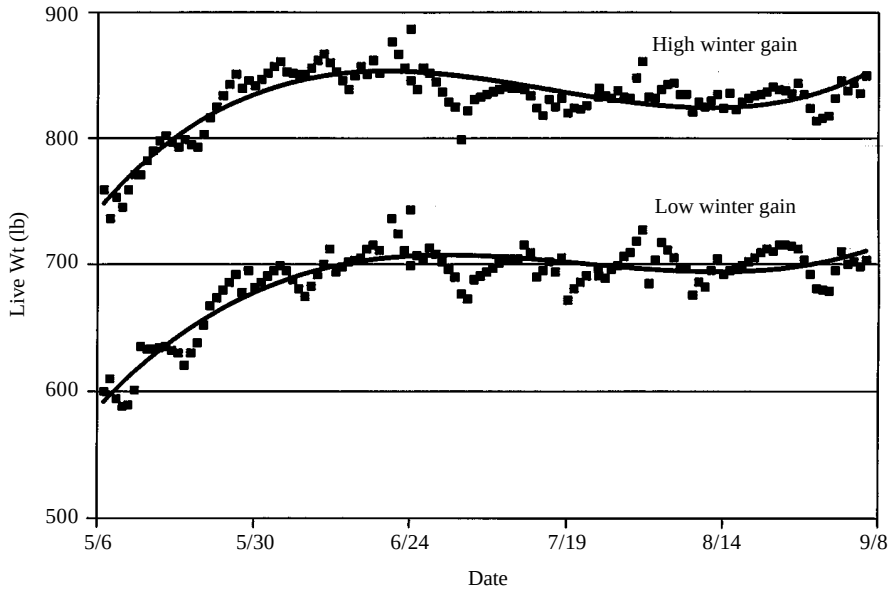

Figure 2. Summer weight gain patterns of steers grazing bromegrass pastures.

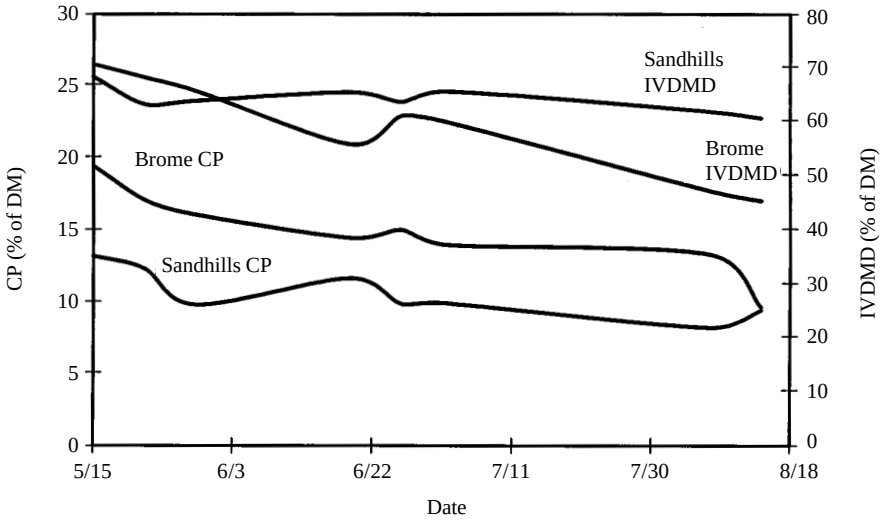

Figure 3. Crude protein and digestibility of summer diets collected from brome pasture and sandhills range.

high-gain winter treatments at each location seemed to exhibit similar growth patterns during summer grazing. The compensatory growth of the low-gain winter cattle most likely occurred gradually, making it difficult to observe a difference in live weight gain patterns between the two groups.

The pasture gains on bromegrass were much lower than in previous years, and is an illustration of the commonly observed "summer slump" of cattle grazing cool-season pasture. Due to several factors, the growth pattern of brome in 1996 was not conducive to optimal cattle performance relative to previous years. May was both unseasonably cool and wet, promoting rapid growth of bromegrass. Because of this, forage quantity exceeded animal demand early in the season, allowing maturation and reduction in quality. Cattle were then forced to graze mature bromegrass in late June and July and considerable trampling occurred. Trampling, in combination with less-than-optimal temperature and moisture in June and July, caused limited forage availability in August.

Figure 3 shows the CP and digestibility changes from May to August at both locations. Protein levels of diets collected from bromegrass pasture imply crude protein did not limit cattle performance to the extent observed. Digestibility of bromegrass decreased from approximately 70% to 45% during the grazing season, while digestibility of sandhills range remained relatively constant. Digestibility values of bromegrass diets reflect rapid forage growth and maturation during the summer and help explain the large performance differences between locations.

During finishing, high-winter-gain cattle summered on brome exhibited higher ($P < .05$) finishing ADG and DMI than low-gain steers at either location. Low- and high-winter-gain cattle grazing bromegrass were more efficient ($P < .05$) than steers grazing sandhills range. The greater efficiency of cattle grazing bromegrass was due to a combination of less weight (low-gain cattle) and less condition upon entering the feedlot. Low-gain cattle from both locations were on feed for more days than high-gain cattle. High-gain steers summered on sandhills range exhibited the lowest ($P < .05$) yield grade, whereas high-gain steers grazed on bromegrass had the highest ($P < .05$) yield grade. Quality grade and liver abscess scores were affected neither by winter treatment nor location.

At both locations, steers on the high-winter-gain treatment maintained approximately 80% of the weight advantage over steers on the low-gain treatment through the summer grazing period. Relative to the low-gain winter treatment, higher winter gain produced heavier steers following summer grazing which finished with fewer days on feed, justifying a rate of winter gain greater than .7 lb/day.

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Summer and Fall Forage Grazing Combinations: Five-Year Summary

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Summer and fall forages that maximize grazing gain in growing finishing systems can reduce slaughter breakeven costs.

Summary

A five-year study using British-breed crossbred cattle included slaughter breakeven analysis and evaluated the effect of grazing alternative summer and fall forages on beef production systems. Grazed summer and fall forage combinations included continuous brome and combinations of brome, warm-season grasses, alfalfa, sudangrass, red clover, native Sandhills range, turnips, rye and cornstalks. The most consistent improvement in summer grazing gain and most desirable slaughter breakeven costs were observed in cattle grazing brome and warm-season grasses or brome and Sandhills range. A reduction in slaughter breakeven cost by grazing fall forages was observed in years with adequate moisture for forage growth. Forages maximizing grazing gain most greatly reduced slaughter breakeven cost.

Introduction

Grazing summer and fall forages is an important component of extensive beef production systems. These systems include a backgrounding period during the winter and spring and a summer and/or fall grazing period followed by a finishing period in the feedlot. Beef production systems based largely on forages are often economical because cost of gain during the grazing period is typically lower than that of a high-concentrate diet. Maximizing grazing gain while production costs will lower the slaughter price required to break-even.

In eastern Nebraska, brome is the predominant grazing forage available. Brome, however, is a cool-season plant and both the quality and quantity of brome can decline during the months of June, July and August. Furthermore, grazing a single forage for the entire grazing period may not allow for maximum gain because of quantity and quality of forage. Using alternative or complementary forages is one method available to balance the distribution of forage growth with the nutritional needs of livestock.

Previous *Nebraska Beef Cattle Reports* have provided the results of research on forage combinations for summer and fall grazing, compared with grazing only one plant species for the entire grazing period. Although these individual reports are important, yearly variation in environmental factors may influence interpretation. This article is a summary of five years of data involving the influence of grazed forage combinations on summer and fall beef cattle gains and evaluates effects of these combinations on economics of the entire growing/finishing system.

Procedure

Data collected during five years was used to evaluate grazing alternative forages during the summer and fall of each year. In each year, British-breed calves were purchased in the fall and allowed a 28-day receiving and acclimation period. Calves were assigned to a low-input wintering period: either grazing cornstalk residue or feeding harvested forages. All calves were fed a protein supplement and allowed free access to a mineral supplement during the stalk grazing and harvested forage feeding periods. Following the winter and spring feeding periods, calves were assigned to grazing treatments.

Summer-forage cattle continuously or rotationally grazed from the first week of May to the first week of September while fall-forage cattle grazed from the first week in September to mid-November. All cattle were implanted with Compudose before summer grazing.

Following grazing, cattle were finished on a high-concentrate corn-based finishing diet formulated (DM basis) to contain 12% CP, .7% calcium, .35% phosphorus, .7% potassium, 25 g/ton monensin and 10 g/ton tylosin. Initial and final weights for each stage were the average of two weights taken on consecutive days following a three-day feeding of a 50% alfalfa hay and 50% corn silage diet (DM basis). Intakes during these periods were limited to 2% (DM) of body weight. Final weights were estimated from hot carcass weight using a 62 dressing percentage. Carcass measurements included hot carcass weight, liver abscess score, fat thickness, quality grade and yield grade.

Breakeven cost was used as the measure of success of each system and included all input costs. Feedlot pen was used as the observation unit for statistical analysis. Breakeven correlation coefficients (r) for amount of gain achieved during the winter/spring period, summer grazing, combined summer and fall grazing and finishing periods were determined to evaluate which period within each system had the most influence on breakeven cost.

Results

In this report, data were pooled from similar grazing treatments whenever possible and analyzed across years. A summary of data for grazing treatments unique to one year, however, are presented in this report with actual data reported in previous *Nebraska Beef Cattle Reports*.

Summer Forages

Grazing brome, then either alfalfa, sudangrass or warm-season grasses, improved summer gains compared with cattle grazing only brome (*Nebraska Beef Cattle Report, MP 58. pp. 21).* However, cattle grazing only brome were more economical (lower slaughter breakeven cost) than cattle grazing brome and sudangrass. Grazing brome and alfalfa or sudangrass increased grazing gain compared to grazing brome alone. However, the added cost of alfalfa or sudangrass production resulted in higher breakeven costs for these systems when compared to grazing brome alone or brome and warm-season grasses. In our research, the cost of producing sudangrass and alfalfa was priced equal to the cost of cash-renting land for corn production plus planting costs. Poloxalene on alfalfa for bloat control adds to the costs. Therefore, the additional summer gain achieved by grazing alfalfa or sudangrass did not offset the additional cost of producing the forage.

Reducing forage production cost by inter-seeding red clover in oats and charging land and production costs against the oats provides an alternative forage for grazing while keeping the cost of the grazed forage to a minimum. However, grazing only red clover has a potential bloat-causing risk. Providing poloxalene to legume-grazing cattle can offset the potential bloat problem, assuming poloxalene consumption is constant.

In a subsequent year (*Nebraska Beef Cattle Report, MP 61. pp. 20)*, systems including red clover grazing had the most desirable slaughter breakeven costs with grazing gains similar to other systems. However, bloat problems requiring removing the cattle from the red clover pastures and placing them back on brome pasture. So, although grazing red clover as an alternative forage improved slaughter breakeven costs, the potential cattle loss due to bloat made the system less desirable due to extra costs of poloxolene supplement and labor to treat animals experiencing bloat.

If either sudangrass or alfalfa were used in lands unsuitable for grain production, grazing costs would equal the cost of producing the forage (seed, planting, labor, etc.), which would, in turn, lower the system's slaughter breakeven cost. Grazing red clover following harvest of a grain crop appears to have potential in improving production systems. Grazing alfalfa, sudangrass or red clover monocultures in addition to brome either proved not economical or potential bloat problems made these systems less desirable.

In two successive years (*Nebraska Beef Cattle Report, MP 66. pp. 48; Nebraska Beef Cattle Report, MP 67. pp. 56)*, native grass resources were utilized in the Nebraska Sandhills to provide a mix of warm-season grasses as an alternative to establishing both cool- and warm-season grass pastures at one location. Grazing a native range with a diversity of plant species allows cattle to select higher-quality forage. In both years, summer gains for cattle grazing systems utilizing Sandhills range, either alone or in combination with brome grazing, were greater (P<.05) compared with cattle grazing only brome, brome and red clover or brome and warm-season grasses (Table 1). However, slaughter breakeven costs for cattle grazing systems utilizing Sandhills range, brome and red clover or brome and warm-season grasses were similar. Cattle grazing continuous brome had the least desirable (P<.05) breakeven cost (Table 1).

Inter-seeding red clover in brome pastures was one attempt at increasing forage quality and quantity during periods when brome quality and quantity is declining. However, stands of red clover inter-seeded in brome pastures were poor in both years. Although gains were not statistically different between cattle grazing red clover/brome and continuous brome, these results indicated interseeding red clover in brome pastures could potentially improve grazing gains compared to cattle grazing only brome.

Data for similar grazing systems (continuous brome and brome/warm-season grass) were pooled and analyzed across years. Cattle grazing brome and warm-season grasses had greater (P<.05) daily gains during the summer compared with cattle grazing only brome (Table 2). During finishing, cattle in the continuous brome system consumed more feed (P<.05), gained

(Continued on next page)

Table 1. Performance and economics for steers grazing brome, brome and warm-season grasses, brome and red clover, brome and Sandhills range or only Sandhills range - a two year summary.

Forage System:	Summer Forages				
Item	Cont. brome	Brome, red clover	Brome, warm-season	Brome, Sandhills range	Sandhills range
Weight, lb					
Initial	488	483	480	478	484
Initial summer	629	624	618	623	625
End summer	805	828	824	883	887
Final	1212	1247	1231	1247	1242
Finishing performance					
DMI, lb/day	29.10[a]	29.43[a]	28.10[b]	29.84[a]	29.33[a]
Daily gain, lb	3.95	4.09	3.98	4.17	4.03
Feed/gain[c]	7.40	7.19	7.09	7.19	7.30
Total costs, $[d]	811.13	812.20	806.74	782.27	785.62
Slaughter Breakeven, $/100 lb	67.01[a]	65.12[b]	65.13[b]	63.67[b]	64.16[b]

[a,b]Means in rows with unlike superscripts differ (P<.05).
[c]Feed/gain analyzed as gain/feed. Feed/gain is the reciprocal of gain/feed.
[d]Includes trucking cost to (one way) Sandhills range increasing breakeven $.912/cwt.

Table 2. Performance data pooled across five years for cattle grazing continuous brome or brome and warm-season grasses.

Item Treatment:	Continuous brome 1	Brome, warm-season 2
Weight, lb		
Initial	453	448
Initial summer	583	577
End summer	771[a]	796[b]
Final	1154	1175
Daily gain, lb		
Winter	.68	.68
Summer	1.59[a]	1.81[b]
Finishing performance		
DMI, lb/day	26.76[a]	25.76[b]
Daily gain, lb	3.59	3.58
Feed/gain[c]	7.46[a]	7.25[b]
Carcass data		
Fat depth, in	.42	.42
Quality grade[d]	18.7	18.7
Yield grade	2.39	2.34

[a,b]Means in rows with unlike superscripts differ ($P < .05$).
[c]Feed/gain analyzed as gain/feed. Feed/gain is reciprocal of gain/feed.
[d]20=average Choice, 19=low Choice, 18=high Select.

similarly and had lower feed efficiencies (P<.05) compared with cattle in the brome, warm-season grass system. No difference in carcass measurements were observed between treatments. Cattle grazing brome and warm-season grasses had more desirable slaughter breakeven costs compared to cattle continuously grazing brome (Table 3). Cattle from the brome and warm-season grass system entered the finishing period with heavier weights and were able to maintain this weight advantage throughout finishing.

Fall forages

Extending grazing past the summer has the potential for further increases in weight gain from forage, reductions in the amount of grain fed and time spent in the finishing phase and improvements in reducing overall slaughter breakeven values. However, extending the grazing season also increases interest cost charged against the animal. Therefore, it is critical fall grazing gains offset the increased interest cost.

Fall forage grazing gains were variable among years, probably due to precipitation variation among years. During years where lack of precipitation reduced fall forage quality and quantity, grazing gains were low and slaughter breakeven costs increased. Gains for cattle grazing turnips were variable among years compared with other forages. Potential yearly variations in moisture, resulting in variable forage quantity from turnips, makes the use of turnips in fall grazing systems less reliable. Grazing rye seeded in wheat stubble appears to have gain-improving potential, but the cost of herbicide to remove rye from the fields in the spring makes this system less desirable.

Quantity and quality consistency of fall forage are major considerations in fall grazing systems. If grazing gains are not sustained during the fall, the increased interest cost and lighter weight of cattle entering the finishing phase will increase slaughter breakeven costs. The most consistently available fall forage available for grazing may be cornstalks.

When cattle enter the finishing phase, following a period of forage grazing, the majority of muscle growth has already occurred. However, sufficient finishing time is still required for cattle to deposit intramuscular fat to improve quality grade. Reducing the amount of time cattle spend in the finishing period without reducing quality grade or fat thickness is one goal of fall grazing. In all years, cattle grazing fall forages were in the finishing phase 16 days less than cattle finished following summer grazing.

In evaluating correlation coefficients among years (Table 4), final finishing weight was negatively correlated (P<.01) with slaughter breakeven cost in all years, indicating a greater final weight lowers breakeven cost. Finishing period daily gain influenced (P<.01) slaughter breakeven cost in two years only, while the amount of summer gain or total grazing gain influenced (P<.10) breakeven cost in four of five years. The influence of the amount of weight gain achieved during the fall grazing period reduced breakeven cost in one year but increased it in another.

The influence of total grazing gain was negatively correlated (P<.03) with days on feed in the finishing period in all years (Table 5) indicating that maximizing forage gain can reduce time spent in the finishing period. The influence of total grazing gain on finishing period daily gain, dry matter intake and feed efficiency was variable among years.

In conclusion, grazing forages that maximized grazing gain, while cost of gain is fixed, reduced overall breakeven cost of production. The most consistent forage combinations in increasing grazing gain and reducing breakeven cost were combinations of brome, warm-season grasses and native range grasses. Grazing forages during the fall may

Table 3. Economic data pooled across years for cattle grazing continuous brome or brome and warm-season grasses.

Item Treatment:	Continuous brome 1	Brome, warm-season 2
Steer cost,$[a]	361.88	358.40
Interest[b]	46.10	45.90
Health[c]	25.00	25.00
Winter costs,$		
Feed[d]	78.95	78.95
Supplement[e]	19.42	19.42
Summer costs,$		
Grazing[f]	40.98	41.94
Finishing costs,$		
Yardage[g]	31.92	31.76
Feed[hi]	173.63	167.08
Days on feed	106.4	105.9
Total costs, $[j]	775.47	765.87
Final wt, lb[k]	1154	1175
Slaughter Breakeven, $/100 lb	66.99[l]	64.99[m]

[a]Initial weight x $80/cwt.
[b]9% interest rate.
[c]Health costs = implants, fly tags, etc.
[d]Receiving costs at $.64/d, Stalk grazing costs at $.12/d; spring feed costs at $.40/d; receiving, winter, and spring yardage costs at $.10/d.
[e]Supplement cost at $.12/d; 1.5 lb/d (as fed).
[f]Grazing costs = $.35/hd/d.
[g]Yardage cost $.30/hd/d.
[h]Average diet cost = $.0543/d (DM) and 9% interest for 1/2 of feed.
[i]Calculated using 15 year average corn price = $2.41/bu.
[j]Total costs includes 2% death loss for each system.
[k]Calculated from hot carcass weight adjusted for 62% dressing percentage.
[l,m]Means in rows with unlike superscripts differ (P<.05).

Table 4. Correlation coefficients (r) for winter, summer, fall, total grazing and finishing gains, and final weight effects on slaughter breakeven cost.

	Year 1		Year 2		Year 3		Year 4		Year 5	
Variable	r	*P*=	r	*P*=	r	*P*=	r	*P*=	r	*P*=
Winter gain	-.24	.379	-.37	.128	-.34	.236	-.09	.750	-.24	.337
Summer gain	-.16	.544	-.46	.056	-.85	.001	-.74	.001	-.81	.001
Grazing gain	.61	.013	-.44	.067	-.69	.007	-.39	.140	-.54	.021
Fall gain	.70	.003	-.31	.215	-.47	.092	.28	.287	-.08	.757
Finishing gain	-.73	.002	-.31	.210	.13	.669	-.72	.002	.23	.343
Final weight	-.73	.002	-.89	.001	-.85	.001	-.78	.001	-.66	.003

Table 5. Correlation coefficients (r) for total grazing gain affecting days on feed, daily gain, feed efficiency, and dry matter intake in the finishing period.

	Year 1		Year 2		Year 3		Year 4		Year 5	
Variable	r	*P*=	r	*P*=	r	*P*=	r	*P*=	r	*P*=
	----------Total grazing gain----------									
Days on feed	-.97	.001	-.88	.001	-.86	.001	-.56	.026	-.93	.001
Daily gain	-.86	.001	.15	.559	-.37	.199	.11	.683	-.75	.003
G/F	-.87	.001	-.22	.386	-.56	.038	-.39	.140	-.79	.001
DMI	.15	.575	.70	.002	.35	.220	.70	.003	.35	.158

potentially reduce breakeven cost compared with grazing only summer forages. However, variable moisture for fall forages results in unpredictable grazing gains and subsequent breakeven costs in fall grazing systems.

A beef production system must be able to withstand yearly environmental differences, such as moisture and temperature which influence quality and quantity of available forage. Although summer gains during this study were different among years, differences among grazing systems should reflect the systems ability to maximize grazing gain.

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Metabolism and Digestibility of Corn Bran and Corn Steep Liquor/Distillers Solubles

Tony Scott
Terry Klopfenstein
Rick Stock
Rob Cooper[1]

Corn steep liquor/distillers solubles lowered pH while feeding corn bran tended to increase pH. Corn steep liquor/distillers solubles fed alone changed the ruminal fermentation pattern of steers.

Summary

Six ruminally cannulated steers and six intact steers were used in a 6x6 Latin square design to determine the effect of corn bran and/or corn steep liquor/distillers solubles on ruminal metabolism and digestibility. Steers fed corn steep liquor/distiller's solubles had lower average daily pH. Corn bran helped maintain a higher average pH. Corn steep liquor/distillers solubles fed alone altered the fermentation pattern of steers. There was a tendency for corn bran to reduce digestibility and for corn steep liquor/distillers solubles to improve digestibility.

Introduction

The corn wet milling industry continues to offer Nebraska cattle feeders opportunities to include byproduct ingredients in their finishing diets. Including byproducts in cattle rations requires a fundamental working knowledge of their effect on nutrient metabolism and their overall effect on animal performance. Corn bran is the fibrous fraction left after corn is wet milled. Corn steep liquor contains the soluble fraction (amino acids, peptides, vitamins, minerals, etc.) of the corn, as well as lactate and other fermentation endproducts. Processing plants producing ethanol have distillers solubles that also may be added back to the corn steep liquor. Previous research at the University of Nebraska has shown a significant interaction between corn bran and corn steep liquor/distillers solubles for gain efficiency . This experiment was designed to determine the effect of corn bran, corn steep liquor/distillers solubles and combinations of the two feed ingredients on metabolism and digestibility.

Procedure

Six ruminally cannulated (873 lb) and six intact (872 lb) steers were used in a 6 x 6 Latin square design (2). The experimental treatment structure was a 2 x 3 factorial with treatments based upon adding corn bran (B), corn steep liquor/distillers solubles (ST) and com-

(Continued on next page)

binations of B and ST to a dry-rolled corn (DRC) control diet. Treatments were DRC, 15%B, 15%ST, 30%ST, 15%B-15%ST and 15%B-30%ST (DM basis). Diets (Table 1) were formulated to contain (DM basis) a minimum of 13% CP, .70 % Ca, .30% P and included 25 g/ton Rumensin and 10 g/ton Tylan. Steers were fed once daily and allowed ad libitum access to diets. Steers were adapted to a 92.5% concentrate diet by using adaptation diets containing (DM basis) 35 (9 d), 25 (9 d) and 15% (7 d) forage.

Ruminally cannulated steers were used to continuously monitor pH and intake using the system described by Cooper et al. (Nebraska Beef Cattle Report, 1997 pp. 49). In addition, rumen fluid samples were taken for VFA analysis. Each period was 14 days: diet adaptation days 1-7, pH and intake measurements days 8-13, and rumen fluid sampling day 14. Samples of rumen fluid were taken every hour for 24 hours beginning at 0900 on day 14. Analyses of VFA were performed on 12 and 24 hour samples and a composite sample of each of the hourly samples.

Intact steers were used to determine the effect of B, ST or combinations of B and ST on total tract digestibility. Each period lasted 14 days: diet adaptation day 1-10 and total fecal collection days 11-14. Feed ingredient samples were taken weekly and feed refusals were weighed daily. Samples of feed refusals were taken for days 9-12 (48 hours before initiation/termination of total fecal collection). Fecal collection bags were weighed, sampled and cleaned twice daily. Samples of feed ingredients, feed refusals and feces were dried in a 60°C oven and composited for analysis. Analyses included DM, CP, NDF and starch.

Results

There were no differences in DMI among steers due to addition of B and/or ST to the DRC basal diet. Steers consumed an average of 2.4 lb of feed in each of 9.5 meals per day with each meal averaging 37.9 min. There were no differences in the number, size or length of meals (data not presented) due

Table 1. Diet Composition.

	Diet[a]					
Ingredient	DRC	15ST	30ST	15B	15B-15ST	15B-30ST
DRC	87.5	73.5	58.5	72.5	58.5	43.5
Bran				15.0	15.0	15.0
Steep		15.0	30.0		15.0	30.0
Alfalfa	7.5	7.5	7.5	7.5	7.5	7.5
Supplement[b]	5.0	4.0	4.0	5.0	4.0	4.0

[a]DRC = dry-rolled corn; B = corn bran; ST = steep liquor/distillers solubles.
[b]Includes vitamins, minerals, and feed additives

Table 2. Intake and pH data from cannulated steers.

	Diet[a]						P=[bc]		
Item	DRC	15ST	30ST	15B	15B-15ST	15B-30ST	B	ST	BxST
DMI, lb	18.7	20.7	17.9	20.2	20.2	21.3	.15	ns	ns
Max pH[d]	6.59	6.59	6.40	6.76	6.61	6.45	ns	.06	ns
Avg pH[e]	6.01	5.92	5.75	6.12	5.95	5.92	.14	.03	ns
Min pH[f]	5.42	5.42	5.25	5.43	5.35	5.50	—	—	.06
pH<5.6 x min[g]	26.8	28.6	138.9	26.2	48.6	5.1	—	—	.01

[a]DRC = dry-rolled corn; B = corn bran; ST = steep liquor/distillers solubles.
[b]Equals P value for effect of corn bran, effect of steep liquor/distiller's solubles and corn bran x steep liquor/distiller's solubles interaction.
[c]ns = not significant (P > .20).
[d]Max pH = maximum pH.
[e]Avg pH = average pH.
[f]Min pH = minimum pH.
[g]pH<5.6 x min =pH x minutes below pH 5.6.

Table 3. Composite VFA analysis.

	Diet[a]						P=[bc]		
Item	DRC	15ST	30ST	15B	15B-15ST	15B-30ST	B	ST	BxST
Acetate[d]	58.6	53.9	49.7	55.1	57.6	55.8	—	—	.09
Propionate[e]	33.6	38.3	41.6	38.6	33.6	33.3	—	—	.05
A:P[f]	1.74	1.41	1.19	1.43	1.71	1.68	—	—	.09
Butyrate[g]	2.39	2.85	2.95	1.96	3.68	4.07	.11	.01	.12
Total VFA, mM	97.6	96.2	96.0	96.7	94.9	91.6	ns	ns	ns

[a]DRC = dry-rolled corn; B = corn bran; ST = steep liquor/distillers solubles.
[b]Equals P value for effect of corn bran, effect of steep liquor/distiller's solubles and corn bran x steep liquor/distiller's solubles interaction.
[c]ns = not significant (P > .20).
[de]Molar proportion.
[f]Acetate to propionate ratio.
[g]Molar proportion.

Table 4. Total tract digestibility.

	Diet[a]						P=[bc]		
Item	DRC	15ST	30ST	15B	15B-15ST	15B-30ST	B	ST	BxST
DMI, lb	17.3	19.4	16.1	18.1	17.9	19.0	ns	ns	ns
DM, %	84.5	87.8	84.5	80.3	83.0	82.4	.05	ns	ns
CP, %	79.4	83.3	79.0	77.1	78.0	81.5	ns	ns	ns
NDF, %	76.0	78.4	71.8	73.8	75.6	82.2	—	—	.05
Starch, %	99.8	99.8	99.8	99.6	99.7	99.7	ns	ns	ns

[a]DRC = dry-rolled corn; B = corn bran; ST = steep liquor/distillers solubles.
[b]Equals P value for effect of corn bran, effect of steep liquor/distiller's solubles, corn bran x steep liquor/distiller's solubles interaction.
[c]ns = not significant (P > .20).

to addition of B and/or ST to the diet.

Laboratory analyses for CP, NDF and starch were determined for DRC, B and ST. The CP contents were 8.2, 12.0 and 26.5% for DRC, B and ST, respectively. Fiber (NDF) contents were 19.8, 78.2 and 0.0% for DRC, B and ST, respectively. Starch contents were 80.7, 23.1 and 15.0% for DRC, B and ST, respectively.

Adding ST to the diet lowered average ruminal pH (Avg pH, Table 2). Corn steep liquor/distillers solubles has an inherently low pH (4.0-4.5), as well as an appreciable amount of lactic acid and unfermented carbohydrates. There was a tendency (P = .14) for B to increase average pH. There was a B x ST interaction for both minimum pH and pH<5.6 x min (Min pH and pH<5.6, Table 2). When ST was fed alone, minimum pH decreased and pH<5.6 x min increased as additional ST was added. However, when B and ST were fed in combination, minimum pH decreased at the 15% level of ST, but did not further decrease with additional ST. Similarly, pH<5.6 x min increased at the 15% level of ST but did not further increase at the 30% level of ST.

Analyses of VFA composite samples (Table 3) resulted in a B x ST interaction for molar proportion of acetate and propionate, as well as acetate to propionate ratio (A:P). When ST was fed alone, acetate decreased, propionate increased and the acetate to propionate ratio decreased as level of ST increased. However, when B and ST were fed in combination, acetate, propionate and acetate to propionate ratio were similar to the DRC control, regardless of the level of ST in the diet. Inclusion of ST in the diet increased the molar proportion of butyrate. Total VFA concentration was not changed by feeding of B and/or ST. The fermentation pattern change that accompanied the feeding of ST alone may help to explain a previous finding: that when ST replaced DRC in the diet it appeared to have a higher energy value (Nebraska Beef Cattle Report, 1997 pp. 72). The high lactic acid content of ST may contribute to the change, due to metabolism of lactic acid to propionate.

Results using intact steers showed no differences in DMI due to inclusion of B and/or ST in the diet (Table 4). Inclusion of B in the diet reduced DM digestibility. Though highly digestible, corn bran is likely slightly less digestible than the DRC it replaced. There was a B x ST interaction for NDF digestibility. The digestibility of CP and starch were not changed by feeding B and/or ST.

Results of this research indicate feeding corn steep liquor/distillers solubles lowers the average ruminal pH of steers. Feeding corn bran may help to maintain a higher average pH. The acetate to propionate ratio of steers is lowered when corn steep liquor/distillers solubles is fed alone. Feeding corn bran reduced dry matter digestibility.

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Effects of Feed Intake Variation on Acidosis and Performance of Finishing Steers

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Intake variation of 4 lb/day did not increase acidosis or decrease performance of finishing steers fed at ad libitum levels of intake. However, intake variation may increase acidosis of limit-fed steers.

Summary

Four metabolism and two finishing trials were conducted to determine the effects of imposed feed intake variation on acidosis and performance of finishing steers. In metabolism trials, intake variation of 3 lb DM/day increased acidosis of limit-fed steers as measured by ruminal pH. However, when steers were fed at ad libitum levels of intake, intake variation of up to 4 lb DM/day did not increase acidosis. In finishing trials, imposed intake variation of 4 lb DM/day neither decreased daily gain nor feed efficiency of steers fed at ad libitum levels of intake.

Introduction

Feed intake variation by cattle fed high-concentrate diets is presumed by most nutritionists and feedlot managers to either predispose or cause digestive disturbances such as acidosis. Despite this commonly held belief, relatively few data are available to evaluate effects of feed intake variation on acidosis and cattle performance. Feed intake variation has also been described as a sign, not necessarily a cause, of subacute acidosis. However, intake variation does not always have a strong negative correlation to cattle performance. Therefore, the cause and effect nature of intake variation and acidosis is unclear. Objectives of these trials were to evaluate the effects of imposed feed intake variation on acidosis and performance of finishing steers.

Materials and Methods

Metabolism Trials.

Four metabolism trials were conducted to determine the effects of

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imposed feed intake variation on acidosis of finishing steers. In Metabolism Trials 1 and 2, four ruminally fistulated steers were used in switchback designs with three 6-day periods. Steers were paired by previous ad libitum intake level and assigned an intake level, within pair, so that the steers averaged approximately 80% of ad libitum intake. In Metabolism Trial 1, treatments consisted of: constant amount of feed given per day (C); and daily feed intake variation of 1.5 lb/day (LV). In Metabolism Trial 2, treatments consisted of: constant amount of feed given per day (C), and daily feed intake variation of 3 lb/day (HV). In Metabolism Trial 3, the same four ruminally fistulated steers from Trials 1 and 2 were fed at ad libitum levels and subjected to three levels of feed intake variation: ad libitum intake with no imposed feed intake variation (AL); daily feed intake variation of 1.5 lb/day (LV); and daily feed intake variation of 3 lb/day (HV). Treatments LV and HV were based on each steer's individual AL intake. Treatments AL, LV and HV were applied to all steers in the 6-day periods of 1, 2 and 3, respectively. In Metabolism Trials 1, 2 and 3, steers were fed a 90% concentrate diet once daily consisting of (DM basis) 78.5% dry-rolled corn, 10% alfalfa hay, 7.8% molasses-urea supplement and 3.7% dry supplement. Rumensin was included in the diets at 25 g/ton.

In Metabolism Trial 4, six ruminally fistulated steers were utilized in a split-plot, crossover design with a 2x3 factorial treatment structure. Treatments consisted of three levels of imposed intake variation: ad libitum intake with no imposed intake variation (AL); daily feed intake variation of 2 lb/day (LV); and daily feed intake variation of 4 lb/day (HV). Treatments LV and HV were based on each individual steer's AL intake. Treatments AL, LV and HV were applied to all steers in periods 1, 2 and 3, respectively. During these periods, steers were assigned randomly to one of two dietary treatments, with or without Rumensin at 25 g/ton. Following period 3, Rumensin treatments were switched, with the three steers receiving Rumensin being assigned to the control diet and the three steers receiving the control diet being assigned to the Rumensin treatment. Following a 15-day wash-out period, treatments AL, LV and HV were then again applied to all steers in periods 4, 5 and 6, respectively. Steers were fed once daily a 92.5% concentrate diet consisting of (DM basis) 81.9% dry-rolled corn, 7.5% alfalfa hay, 6.4% molasses-urea supplement and 4.2% dry supplement.

In metabolism trials, steers were tethered in individual metabolism stalls. Individual feed bunks were suspended from load cells and monitored continuously. Ruminal pH also was monitored continuously with submersible pH electrodes suspended through the plug of the ruminal cannula of each steer. Each electrode was encased in a weighted four-wire metal shroud to keep the electrode in a stationary position approximately 5 inches above the ventral floor of the rumen, while allowing rumen contents to flow freely through it. Load cells and pH electrodes were linked directly to a computer, allowing data acquisition software to record both a feed weight and ruminal pH for each steer every minute during the six-day collection periods.

Finishing Trials.

Two finishing trials were conducted to evaluate the effect of imposed feed intake variation on performance of finishing steers. In Finishing Trial 1, 75 crossbred yearling steers (average initial weight = 620 lb) were blocked by weight and assigned randomly to one of two treatments (4 replications per treatment). Treatments consisted of two levels of imposed feed intake variation: ad libitum with no imposed feed intake variation (AL); or daily intake variation of 4 lb/day (HV). The finishing diet contained (DM basis) 51.7% dry-rolled corn, 35% high moisture corn, 5% alfalfa hay, 3.3 % corn silage and 5% dry supplement. Rumensin was included in the diet at 25 g/ton and Tylan at 10 g/ton. Steers were implanted with Revalor-S and fed for 140 days.

In Finishing Trial 2, 94 crossbred yearling steers (average initial weight = 656 lb) were assigned randomly to one of 12 pens. Pens were allotted randomly to one of two dietary treatments and to one of two levels of intake variation. Dietary treatments consisted of either control diet balanced for typical commercial feedlot CP and P levels or a diet balanced to match MP and P requirements using the NRC model (1996). The control diet contained (DM basis) 81.3% dry-rolled corn, 7.5% alfalfa hay, 6.7% molasses-urea supplement and 5% dry supplement. The balanced diet contained (DM basis) 64.5% high moisture corn, 20.1% corn bran, 7.5% alfalfa hay, 5% dry supplement and 2.9% tallow. In both diets, Rumensin was included at 25 g/ton and Tylan at 10 g/ton. Steers were fed for 147 days and were implanted with Revalor-S at the beginning, and again after 80 days on feed. Levels of intake variation consisted of ad libitum intake with no imposed feed intake variation (AL) or daily feed intake variation of 4 lb/day (HV). Dietary treatments were part of a separate trial with different objectives. Therefore, the only level of intake variation means presented are those which did not have a significant interaction ($P > .10$).

In both finishing trials, steers on the HV treatment were fed ad libitum from day 1 through day 34. Then, based on each pen's average DMI from day 28 through day 34, each pen was subjected to imposed feed intake variation of 4 lb/day from day 35 through slaughter (140 and 147 days on feed for Finishing Trials 1 and 2, respectively). This was accomplished by first decreasing the feed offered by 2 lb from each pen's average DMI on day 36. Feed offered was increased by 4 lb on day 37, decreased by 4 lb on day 38, increased by 4 lb on day 39 and so on. In order to maintain the average amount of feed offered at ad libitum levels, a 1 lb/day adjustment factor was used. For example, if feed remained in the bunk on the morning following a low-level offering day (-4 lb), only 3 lbs was offered, decreasing the average feed offered to the steers by 1 lb. On the other hand, if a bunk was slick on the morning following a high-level offering day,

Table 1. Effects of imposed low intake variation on limit-fed steers in Metabolism Trial 1.

	Treatment		
Item	Constant[a]	Low intake variation[b]	SEM
Daily DMI, lb	17.9	17.4	2.2
Rate of intake, %/h	53.4	67.0	31.2
Average ruminal pH	5.95	5.85	.26
Area of ruminal pH below 5.6[c]	97.7	151.7	63.7

[a]Constant amount of feed offered per day at approximately 80% of ad libitum intake.
[b]Daily intake variation of 1.5 lb/day based on the level of feed offered in the Constant treatment.
[c]Area = magnitude of ruminal pH below 5.6 by min.

Table 2. Effects of imposed high intake variation on limit-fed steers in Metabolism Trial 2.

	Treatment		
Item	Constant[a]	High intake variation[b]	SEM
Daily DMI, lb	18.1	18.1	2.0
Rate of intake, %/h	46.0	70.7	22.6
Average ruminal pH	5.84	5.82	.23
Area of ruminal pH below 5.6[cd]	106.2	180.9	83.7

[a]Constant amount of feed offered per day at approximately 80% of ad libitum intake.
[b]Daily intake variation of 3 lb/day based on the level of feed offered in the Constant treatment.
[c]Area = magnitude of ruminal pH below 5.6 by min.
[d]Means differ ($P<.05$).

Table 3. Effects of imposed intake variation on steers fed at ad libitum levels in Metabolism Trial 3.

	Treatment			
Item	Ad libitum[a]	Low variation[b]	High variation[c]	SEM
Daily DMI, lb	21.8	21.6	21.9	4.2
Rate of intake, %/h	22.2	25.6	24.5	4.1
Average ruminal pH	5.63	5.63	5.67	.17
Area of ruminal pH below 5.6[d]	227.4	187.0	180.0	87.0

[a]Ad libitum intake with no imposed intake variation.
[b]Daily intake variation of 1.5 lb/day based on the level of feed offered in the Ad libitum treatment.
[c]Daily intake variation of 3 lb/day based on the level of feed offered in the Ad libitum treatment.
[d]Area = magnitude of ruminal pH below 5.6 by min.

Table 4. Effects of imposed intake variation on steers fed at ad libitum levels in Metabolism Trial 4.

	Treatment			
Item	Ad libitum[a]	Low variation[b]	High variation[c]	SEM
Daily DMI, lb	28.8	27.9	27.9	2.2
Rate of intake, %/h	31.4	37.9	35.9	6.3
Average ruminal pH[d]	5.55	5.68	5.76	.07
Area of ruminal pH below 5.6[de]	215.8	154.1	94.7	52.6

[a]Ad libitum intake with no imposed intake variation.
[b]Daily intake variation of 2 lb/day based on the level of feed offered in the Ad libitum treatment.
[c]Daily intake variation of 4 lb/day based on the level of feed offered in the Ad libitum treatment.
[d]Linear ($P<.05$).
[e]Area = magnitude of ruminal pH below 5.6 by min.

(+4 lb), the amount offered only decreased by 3 lb, increasing the average feed offered to the steers by 1 lb. By using this system, feed intake variation could be imposed on individual pens based on individual ad libitum intakes.

Results

Metabolism Trials.

In Metabolism Trial 1, no significant differences in DMI, rate of intake, average ruminal pH or area of ruminal pH below 5.6 ($P>.10$) were noted between treatments of C or LV of 1.5 lb/day (Table 1). In Metabolism Trial 2, no significant differences in DMI, rate of intake and average ruminal pH ($P>.10$) were noted between treatments of C and HV of 3 lb/day (Table 2). However, area of ruminal pH below 5.6 was increased ($P<.05$) by 75 units (magnitude of pH below 5.6 by min) in the HV treatment compared with C.

Results of Metabolism Trial 1 indicate daily intake variation of 1.5 lb/day does not significantly alter measures of intake or acidosis within a limit-feeding system. However, there were numerical trends for increased rate of intake and area of ruminal pH below 5.6 and decreased average ruminal pH with the LV treatment compared with C. Results of Metabolism Trial 2 indicate intake variation of 3 lb/day increased acidosis in steers as measured by the area of ruminal pH below 5.6, within a limit-feeding system. In addition, rate of intake numerically increased with the HV treatment, although not significantly. Although Metabolism Trials 1 and 2 were separate, they were consecutive and utilized the same steers. Therefore, these two trials indicate that there may be a linear response of increased acidosis with increasing levels of imposed feed intake variation within a limit-feeding system. Note, though, that average ruminal pH would not have provided the same conclusions as it was not significantly affected in either trial. Because area of ruminal pH below 5.6 should provide a more accurate measure of acidosis, conclusions were based on this parameter.

In Metabolism Trial 3, with the treatments of AL, LV of 1.5 lb/day and HV of 3 lb/day, no differences in DMI, rate of intake, average ruminal pH or area of ruminal pH below 5.6 ($P>.10$) were noted (Table 3). However, although not significant ($P=.28$, AL versus HV), area of ruminal pH below 5.6 numerically decreased as level of intake variation increased. The same steers, fed under the same general conditions, responded differently to imposed intake variation

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when fed at ad libitum levels of intake compared with being limit-fed.

In Metabolism Trial 4, with the treatments of AL, LV of 2 lb/day and HV of 4 lb/day, DMI was not affected by level of intake variation and averaged 28.2 lb/day (Table 4). Rate of intake tended (P=.13) to increase for both LV and HV compared with AL; but the LV and HV treatments did not differ. Average ruminal pH increased linearly (P<.01) across the treatments of AL (0), 2 and 4 lb/day of imposed intake variation, and area of ruminal pH below 5.6 decreased linearly (P<.05) as level of intake variation increased. Both measurements indicate a reduction in acidosis as the level of intake variation was increased.

The results of Metabolism Trials 3 and 4 suggest steers fed at ad libitum levels of intake do not experience increased acidosis with imposed intake variation of up to 4 lb/day. In fact, the results support a reduced incidence of acidosis with increased level of intake variation. This, however, is difficult to explain. One explanation might be that when the steers were subjected to intake variation, days of reduced feed allowed the steers to build buffer capacity or base-excess, so acidosis was not induced even with over-consumption the following day. However, this is speculation. Further work with rumen and blood metabolites is needed in this area. One thing is clear: steers fed at ad libitum levels under these trial conditions did not experience more acidosis with increased intake variation.

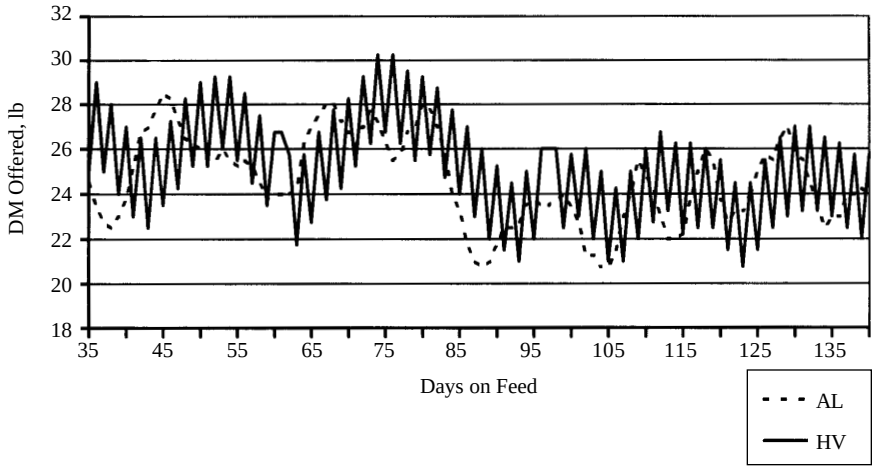

Figure 1. Dry matter offered during Feedlot Trial 1.

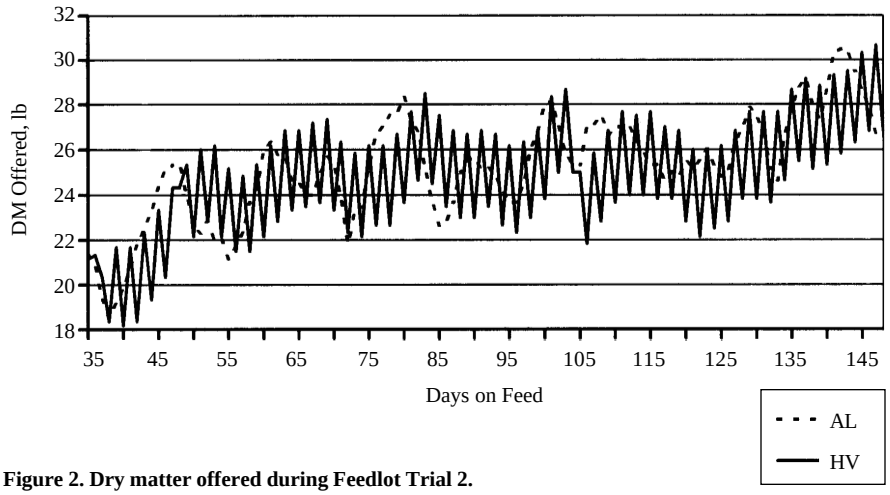

Figure 2. Dry matter offered during Feedlot Trial 2.

Finishing Trials.

Dry matter offered to pens of cattle in Finishing Trials 1 and 2 are shown in Figures 1 and 2, respectively. In these figures, DM offered is averaged by level of intake variation for day 35 through slaughter. Although these figures depict feed offered, actual DMI should be similar as the daily amount offered was adjusted so feed would not accumulate in the bunk. The overall pattern of DMI was very similar between levels of intake variation for both trials. However, there was a much higher degree of day-to-day intake variation in the pens on the HV treatments, predictable due to the imposed intake variation of 4 lb/day. In both finishing trials, the average absolute daily change in amount of DM offered was 1 lb/day for AL and 3 lb/day for HV. It is important to note DMI was not constant for pens on the AL treatment, where the daily amount of feed offered was adjusted in order to avoid both feed accumulation and an empty bunk.

In Finishing Trial 1, overall DMI was higher (P<.05) in the HV treatment compared with the AL treatment (Table 5). However, due to intake variation, no differences in daily gain or feed efficiency (P>.10) were noted.

In Finishing Trial 2, there were no interactions (P>.10) between dietary treatment and imposed intake variation. Therefore, only the overall means for intake variation are presented (Table 6). No differences in DMI, daily gain or feed efficiency were noted due to intake variation.

The results of Metabolism Trials 3 and 4 and Finishing Trials 1 and 2 indicate imposed intake variation of up to 4 lb/day neither increased acidosis nor decreased performance of finishing steers fed at ad libitum levels of intake. However, results of Metabolism Trials 1 and 2 indicate intake variation in a limit-feeding system may increase the incidence of subacute acidosis.

It is important to note the intake variation in these trials was imposed and "consistent". Steers may have

Table 5. Effects of imposed intake variation on performance of steers fed at ad libitum levels in Finishing Trial 1

Item	Treatment		SEM
	Ad libitum[a]	Intake variation[b]	
Daily DMI, lb[c]	23.7	24.1	.1
Daily gain, lb	3.75	3.84	.06
Gain/DMI	.159	.159	.003

[a]Ad libitum feed offered with no imposed intake variation.
[b]Daily intake variation of 4 lb/day from days 35 through slaughter.
[c]Means differ ($P<.05$).

Table 6. Effects of imposed intake variation on performance of steers fed at ad libitum levels in Finishing Trial 2

Item	Treatment		SEM
	Ad libitum[a]	Intake variation[b]	
Daily DMI, lb	24.5	24.3	.2
Daily gain, lb	4.06	3.96	.05
Gain/DMI	.165	.163	.003

[a]Ad libitum feed offered with no imposed intake variation.
[b]Daily intake variation of 4 lb/day from days 35 through slaughter.

adapted to the routine of imposed changes and therefore were less affected. On the other hand, random occurrences of intake variation, such as a weather change or mill breakdown, may increase the incidence of acidosis. These data suggest that finishing cattle can naturally vary their intake (up to 4 lb/day and maybe more) without creating acidosis or reduced performance.

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Observations on Acidosis Through Continual Feed Intake and Ruminal pH Monitoring

Rob Cooper
Terry Klopfenstein
Rick Stock
Cal Parrott[1]

A system of continually monitoring feed intake and ruminal pH of finishing steers has provided many opportunities for making anecdotal observations of subacute acidosis during the finishing period.

Summary

A system of continual data acquisition of feed intake and ruminal pH has been developed for studying subacute acidosis in finishing steers. Feed intake is monitored with feedbunks which are suspended from weigh cells. Ruminal pH is monitored with submersible pH electrodes suspended in the rumen. Numerous anecdotal observations of subacute acidosis have been made throughout the feeding periods of several steers, providing information unlikely to be recognized during a planned trial. Therefore, this model for studying subacute acidosis offers many unique opportunities for enhancing our understanding of the interactions between feed intake and acidosis.

Introduction

The cattle feeding business in the United States has evolved into an intensively managed, production-oriented industry. Due to costs associated with interest on cattle, yardage in the feedlot and the price and inconvenience of roughages, economics usually favor rapidly increasing the grain portion of the diet to put the cattle on a high concentrate diet as soon as possible. However, both the rapid increase in concentrate and low roughage levels in the finishing diet increase the potential for subacute acidosis.

Subacute acidosis is generally characterized as ruminal pH between 5.6 and 5.2. Ruminal pH below 5.2 is indicative of acute acidosis. The major response seen with subacute acidosis is reduced intake; therefore subacute acidosis is more subtle and more difficult to access than acute acidosis. Even in metabolism studies it is difficult to measure all the effects of subacute acidosis, because as ruminal pH declines cattle adjust by decreasing feed intake and alter their eating patterns. However, subacute acidosis continues to be a major factor limiting feedlot cattle performance. Several models have been used to study subacute acidosis. One model, the evaluation of intake variation of individually fed cattle (1991 Nebraska Beef Report, pp. 55), is based on the premise that intake variation is caused by subacute acidosis. Therefore, subacute acidosis can be evaluated by monitoring the magnitude of feed intake variation. The second model is a steer metabolism model (1993 Nebraska Beef Report, pp. 60). Fistulated cattle are challenged with sufficient grain to create subacute acidosis. The challenge, usually half-corn and half-wheat, is placed directly in the rumen, and the ruminal pH determined

(Continued on next page)

at 3-hour intervals over a 24-hour period. These two models have been very useful in the study of acidosis; however, each has limitations. The challenge used in the steer metabolism model may not be appropriate for the study of subacute acidosis as it may overwhelm the system. While erratic day-to-day intake variation is indicative of subacute acidosis, within-day intake patterns have not been evaluated directly in the intake variance model. Therefore, it was desirable to develop a more complete subacute acidosis model. A system of continual acquisition of feed intake and ruminal pH was developed so a more complete understanding of the interactions between ruminal pH and feed intake would be possible.

Procedure

Continuous data acquisition of feed intake and ruminal pH has been collected on many steers throughout several different trials. In some of these trials, subacute acidosis has been monitored during the grain adaptation period. Feed intake and ruminal pH data also have been gathered on numerous steers during periods of subacute acidosis induced by varying dry matter intake of steers fed a high concentrate diet, directly placing grain in the rumen and late feeding. The results from these trials have been previously reported. However, in this report, observations and comments will be made concerning interesting situations and anecdotal events which have occurred throughout the large amount of data collected.

During all trials in which these data were collected, steers were tethered in individual metabolism stalls. Feed intakes were monitored with individual feedbunks suspended from weigh cells. Ruminal pH was monitored with submersible pH electrodes suspended through the plug of the rumen cannula of each steer. Each pH electrode was encased in a weighted, four wire metal shroud to keep the electrode in a stationary position 5 inches above the ventral floor of the rumen while allowing rumen contents to flow freely through it. Weigh cells and pH electrodes were linked directly to a computer allowing data acquisition software to record both a feed weight and a ruminal pH every minute for each steer during collection periods.

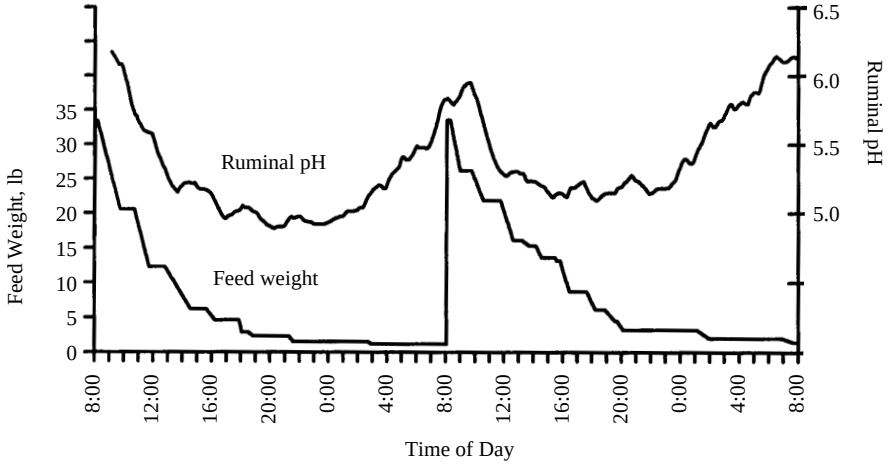

Figure 1. Feed intake and ruminal pH of a steer over a two-day period on a finishing diet (92.5% concentrate).

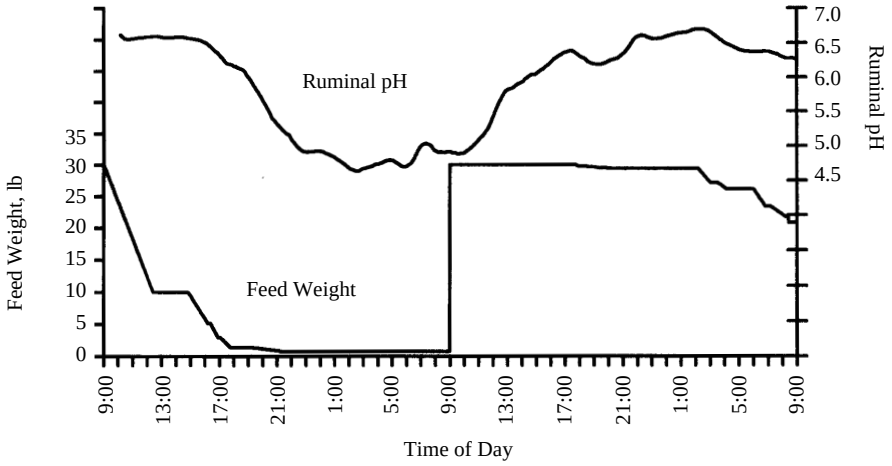

Figure 2. Feed intake and ruminal pH of a steer during the first and second day on feed (55% concentrate).

Although steers were tethered in metabolism stalls, both intake and animal performance have been favorable in all trials. It was not uncommon for the yearling steers used in these trials to consume over 25 lb of dry matter and to gain approximately 4 lb per day.

Results

Examples of feed weight and ruminal pH data collected are shown in Figure 1, which depicts the two-day intake and ruminal pH of a steer in the middle of the finishing period. This steer was fed a 92.5% concentrate, dry-rolled corn-based diet once daily at 0800. Figure 1 also shows the typical cyclic pattern of ruminal pH, which is usually highest at feeding and declines to its lowest point 5-10 hours later. The graph for feed weight in Figure 1 actually shows feed disappearance from the bunk. Therefore a meal is depicted when the feed weight line declines. As Figure 1 shows, this steer ate at a more rapid rate and consumed larger meals on day 1 than on day 2. The effects of these intake patterns are reflected in the ruminal pH, which dropped lower and stayed lower longer during the first day than compared to the second. This figure shows the truly cyclic nature of ruminal pH and its relationship to feed intake. Ruminal pH was relatively high at the beginning of the first day which probably promoted (or at least did not

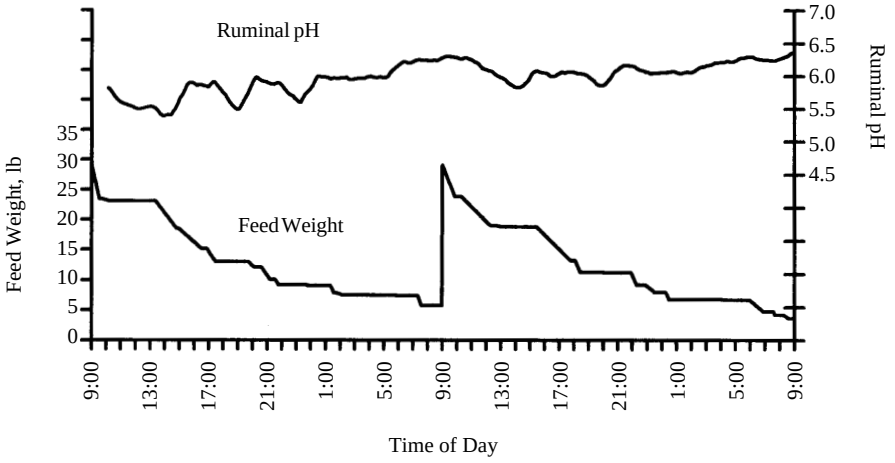

Figure 3. Feed intake and ruminal pH of same steer as in Figure 2, first and second day of step 2 (65% concentrate).

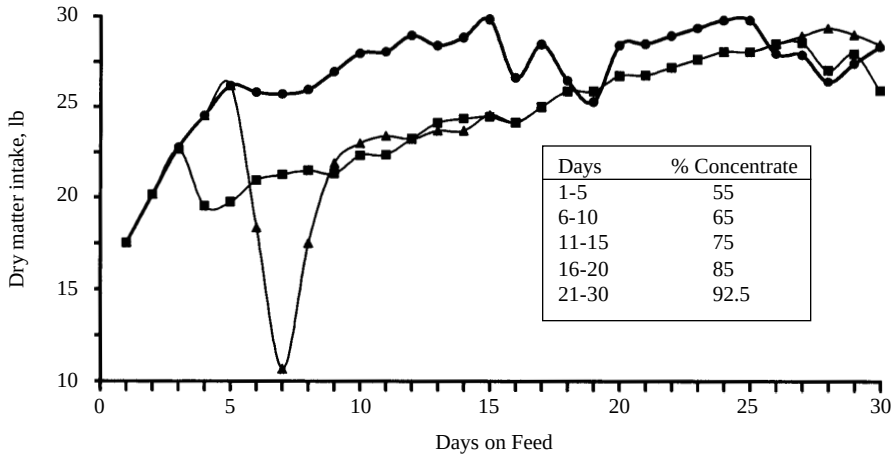

Figure 4. Dry matter intake of three steers during grain adaptation.

hinder) the rapid rate of intake. As a result of the rapid intake during day one, ruminal pH dropped to a level indicative of subacute acidosis. Rate of intake was not as rapid during the second day. This is likely due to both the low ruminal pH experienced during day 1 and to a lower initial ruminal pH at feeding time during day 2. During day 2, it appears the steer consumed feed at a rate which prevented ruminal pH from dropping to the first day's level. It is important to note the steer consumed approximately the same amount of feed on both days. However, the intake patterns had significant effects on ruminal pH and acidosis.

Figure 2 shows the feed intake and ruminal pH of a steer which experienced acidosis during the first day of step 1 of the grain adaptation period. Previously, this steer had been offered alfalfa hay ad libitum. Figure 2 shows the first and second day of step 1, a 55% concentrate dry-rolled corn-based diet. This steer consumed the diet very rapidly on day 1, eating approximately 30 lb (as-fed) in only two meals. Consequently, ruminal pH dropped to approximately 5.0 and did not increase until the next morning. The following day, the steer was offered the same amount of feed but did not consume a meal until about midnight and then only ate approximately 7 lb (as-fed) in several small meals. Even on only a 55% concentrate diet, a steer can become acidotic if the diet is consumed too rapidly. This figure clearly shows the relationship between feed intake and ruminal pH and how an acidotic steer will adjust intake to return ruminal pH to a normal level. It is likely this steer learned from this experience and was consequently less aggressive at the feedbunk later in the feeding period to avoid acidosis. Figure 3 shows the feed intake and ruminal pH of the same steer on day 1 and day 2 of step 2, a 65% concentrate diet (days 5 and 6 on feed). During these days, the steer ate at a slower rate, consuming small meals throughout the day. As a result, ruminal pH stayed relatively high and constant compared to the two days in Figure 2. Both figures show how a steer learns to adjust intake pattern during grain adaptation in order to avoid acidosis.

Figure 4 shows the dry matter intake of three steers during the grain adaptation period. Steers were fed a dry-rolled, corn-based diet once daily at ad libitum levels. Step-up diets consisted of 45% (d 1-5), 35% (d 6-10), 25% (d 11-15), 15% (d 26-20) and 7.5% alfalfa hay (day 21-30) in place of dry-rolled corn. Figure 5 shows the average daily ruminal pH (average of 1,440 observations per steer per day) of the same three steers during the grain adaptation period. In Figure 4, notice the steer represented by triangles steadily climbed in intake during step 1, but dramatically dropped in intake the first and second days of step 2. Figure 5 shows that as the steer was building intake during step 1, its average ruminal pH was steadily decreasing, reaching approximately 5.3 on the last day of step 1. Even if this steer had not been moved to the next step-up diet the next day, he likely would have decreased intake. To compound the steer's existing acidosis problem, step 2 (65% concentrate) was offered on day 6, further reducing average ruminal pH and causing the steer to dramatically reduce intake for several days. In retrospect, there may be two different ways to conduct the feed calling for this steer: 1) either offer enough feed during step 1, or extend step 1, until this steer was "caught" (leaving feed in the bunk) reducing its aggression during step 2; or 2) prohibit this steer from building so high an intake on step 1, so that the increase in concentrate would not so drastically impact ruminal pH. The latter method,

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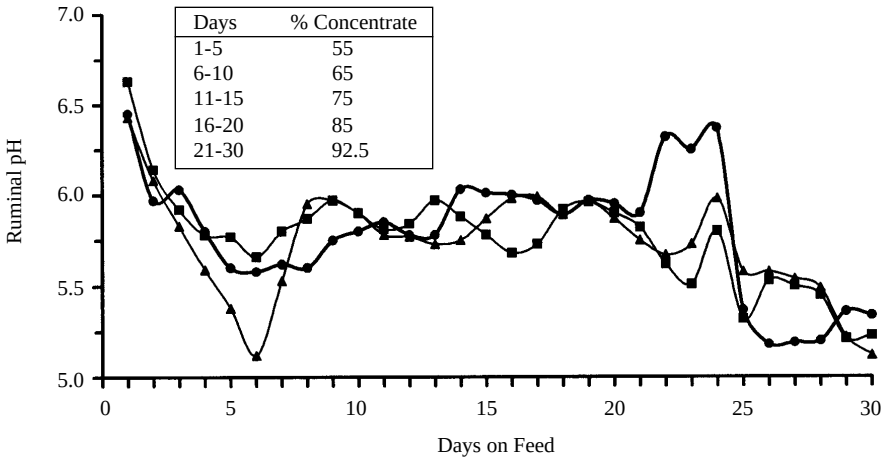

Figure 5. Average daily ruminal pH of three steers during grain adaptation.

however would encourage more rapid rates of intake, which can create acidosis even with diets relatively high in roughage, as shown in Figure 2.

Figure 5 shows another interesting anecdotal event which occurred during these steers' grain adaptation period. The figure shows that on day 24, average ruminal pH consistently increased for all three steers. On this day, a feeding mistake occurred and the steers, which were usually fed at 0800 each day were not fed until 1200. When the steers were fed, they were only given 5-10 lb at a time about every two hours to help keep them on feed. Day 24 is the fourth day on the finishing diet (92.5% concentrate), probably one of the most critical days during the grain adaptation period. It is important to note these steers were at ad libitum levels of intake and that all had some feed left in the bunk on the morning of day 24. However, by 1200 all of the bunks were slick and the steers were somewhat aggressive. Average ruminal pH likely increased on this day because the steers were out of feed for about four hours, after which they were offered feed spread out over an extended period of time. On day 25, steers were given their feed as normal. Figure 5 shows the dramatic decrease in average ruminal pH on day 25 and thereafter. As indicated by both the very low ruminal pH and slightly reduced intakes, the steer represented by circles in Figure 5 suffered subacute acidosis for several days following the feeding mistake. It is important to note these values are average daily ruminal pH; minimum daily ruminal pH reached below 5.0 for all three steers during this period. It is interesting to note that later in this trial period there were unsuccessful attempts to induce subacute acidosis by fluctuating dry matter intake by 4 lb per day. Feeding four hours late had a much more substantial effect on acidosis than intake variation of 4 lb per day. This suggests consistency and timing of feeding are critical management components in order to avoid acidosis.

These are just a few examples of anecdotal events and observations made with this system of continual feed intake and ruminal pH monitoring. Often these observations are as interesting and informational as the results collected from the respective trial. One important point needs to be emphasized. Acidosis affects individual cattle. Through continual monitoring of feed intake and ruminal pH of individual steers, it is evident that virtually all steers experience varying degrees of subacute acidosis sometime during feeding. It is unlikely, however, that these bouts would ever be noticed in a feedlot pen. Although a complete pen of cattle may not be "off feed", individual cattle are likely experiencing bouts of subacute acidosis. Many times, this acidosis goes unnoticed because individuals with reduced intake are "averaged out" by the other cattle in the pen not experiencing acidosis.

Phosphorus Requirement of Finishing Yearlings

Galen Erickson
Mark Klemesrud
Todd Milton
Terry Klopfenstein[1]

The phosphorus requirement for finishing yearlings is 0.14 % of dietary DM or less, suggesting phosphorus supplementation in corn-based diets fed to yearlings is unnecessary.

Summary

Sixty yearling crossbred steers (849 lb) were fed individually either 0.35 or 0.70 % of DM as Ca and 0.14, 0.19, 0.24, 0.29 or 0.34 % P. Ash content was determined on bones from the lower front legs and one rib from each carcass was used to determine breaking strength. Performance and bone characteristics were not affected by dietary P concentration or P intake. Steers fed the 0.70 % Ca diets had lower gains and poorer efficiencies when compared to those fed 0.35 % Ca. These results indicate the requirement for finishing yearlings is 0.14 % P or less and it is not necessary to supplement P in typical finishing diets fed to yearling steers, as corn is usually greater than 0.25 % P.

Introduction

Manure management is a critical issue. Phosphorus can limit the amount of manure applicable to cropland as P doesn't volatilize, while 50 % or more of the N is lost as ammonia. Given P isn't volatile and doesn't leach as N, surface excesses of P can be an impor-

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Table 1. Diet composition (% of diet DM).

ITEM [a]	Low P, Low Ca	High P, Low Ca	Low P, High Ca	High P, High Ca
DRC	34.5	34.5	34.5	34.5
BRAN	22.5	22.5	22.5	22.5
GRITS	22.5	22.5	22.5	22.5
COBS	7.5	7.5	7.5	7.5
Molasses	5.0	5.0	5.0	5.0
Fat	3.0	3.0	3.0	3.0
Suppl.[b]	5.0	5.0	5.0	5.0
limestone	0.75	0.75	1.67	1.67
salt	0.30	0.0	0.30	0.0
sodium phosphate	0.0	0.72	0.0	0.73
CP	12.0	12.0	12.0	12.0
Ca	0.35	0.35	0.70	0.70
P	0.14	0.34	0.14	0.34

[a]Dry-rolled corn, corn bran, brewers grits and ground corncobs
[b]Supplement contained tr.min., vit., rumensin/tylan, KCl, urea and carrier

Table 2. Animal performance as influenced by P and Ca.

% P	P intake g/d	ADG lb/d	DMI lb/d	Feed/ gain [c]	HCW [d] lb	Fat [e] inches	QG [f]
0.14	15.9	3.87	25.0	6.49	776	0.41	17.9
0.19	19.7	3.57	22.8	6.37	755	0.40	18.7
0.24	27.6	3.77	25.2	6.71	776	0.42	18.5
0.29	32.1	3.85	24.4	6.33	774	0.43	17.9
0.34	36.4	3.38	23.6	7.04	745	0.43	18.9
SE	.74	.20	.73		21	.03	.34
% Ca							
0.35		3.88 [a]	24.4	6.29 [a]	776	0.41	18.2
0.70		3.50 [b]	24.0	6.90 [b]	755	0.43	18.5
SE		.13	.47		14	.02	.21

[a,b]Means within a column with unlike superscripts are different (P<.05)
[c]Analyzed as gain to feed, the reciprocal of feed to gain.
[d]Hot carcass weight
[e]Fat depth at 12th rib
[f]Quality grade where 18 = Select+, 19 = Choice-

tant concern if surface runoff is not completely controlled. Dietary manipulations decreasing P in the manure can alleviate some of these concerns.

Since ruminants can utilize organic (phytate) P, supplementation may not be as critical as previously thought. In addition, previous research was conducted with younger calves which were not fed high-energy rations and gained less than 1 to 1.5 lbs/d. Our objective with this study was to determine the P requirement of yearling cattle fed a high-energy diet.

Procedure

From September 4 to December 18, 1996 (105 d), 60 yearling crossbred steers (BW = 849 lb) were individually fed once daily using Calan gates. Steers were randomly assigned using a 2 X 5 factorial design to one of 10 treatments (6 hd/trt). Treatments consisted of two levels of Ca, either 0.35 or 0.70 % of dietary DM, with limestone as the source of supplemental Ca. Within each Ca level were five levels of P, either 0.14 which contained no supplemental P, 0.19, 0.24, 0.29 or 0.34 % of dietary DM. Supplemental P was provided by mono-sodium phosphate (NaP) instead of dicalcium phosphate to allow the Ca levels to remain constant at all P levels. Two supplements (no P and high P) for each Ca level were blended at time of feeding to achieve appropriate levels of supplemental P.

Diets (Table 1) contained 34.5 % dry-rolled corn (DRC), 22.5% brewers grits, 22.5 % corn bran, 7.5 % ground corncobs, 5.0 % molasses, 3.0 % fat and 5.0 % supplement on a DM basis. Since DRC contains 0.25 to 0.30 % P, brewers grits and corn bran were fed to decrease the dietary P level to 0.14 %. Both feedstuffs are high in energy and corn products, with grits being primarily corn starch and bran consisting of the digestible corn fiber. Diets were formulated for 12.0 % protein and contained 25 g/ton Rumensin and 10 g/ton Tylan. Steers were adapted to finisher rations by limiting intake and gradually increasing DM offered until ad libitum intakes were attained. Steers were implanted on day 1 with Revalor-S. Steers were housed in covered pens with 30 hd/pen. Initial weights were the average of weights taken before feeding on three consecutive days. Final weights were calculated from hot carcass weight divided by a common dressing percentage (62). Liver abscess scores and hot carcass weights were recorded at slaughter. Quality grade, yield grade and fat thickness at the 12th rib were recorded after a 36 hour chill.

Status of P in bone is a good indicator of whether the P requirement has been met. The animal can not distinguish P and only resorb that mineral from bone. Instead, the animal must breakdown the entire complex to mobilize P. At slaughter, two bones (first phalanx) were collected from each front leg to determine total mineral content. One rib was also collected from each carcass to determine breaking strength. After collection, each bone was trimmed of soft tissue and frozen until analysis. Phalanx bones were ashed for 24 hr at 600°C to determine total mineral. The ribs were thawed and broken on an Instron Universal Testing Machine for an objective measure of bone strength.

Results

Because there were no interactions between Ca and P levels, only main effects for P (n=12) and Ca (n=30) are presented (Table 2). Dry matter intake (DMI), ADG and feed efficiency were

(Continued on next page)

Table 3. Bone characteristics with main effects of P and Ca.

	Phalanx		Ribs			
% P	total ash (grams)	% ash (g/100 kg HCW)	bone area (mm^2)	AUC[c] (mm^2)	peak[d] (lbs)	time[e] (mm)
0.14	28.29	8.01	275	505	784	19.9
0.19	27.51	8.02	262	516	741	20.8
0.24	28.86	8.20	267	504	770	20.1
0.29	27.50	7.83	269	502	759	21.3
0.34	28.52	8.46	283	477	796	18.3
SE	.98	.20	10	30	44	1.2
% Ca						
0.35	28.01	7.96	269	502	735[a]	21.0[a]
0.70	28.26	8.25	273	500	805[b]	19.2[b]
SE	.62	.13	6.5	19	26	.8

[a,b]Means within a column with unlike superscripts are different (P<.10).
[c]Area under curve, measure of peak force and time for breaking strength.
[d]Peak force required to break rib.
[e]Time required to break rib.

similar across P levels. Although intakes were variable due to individual feeding, no consistent trends (linear, quadratic, or cubic) were evident due to P intake. Steers fed 0.70% Ca had numerically lower DMI and gained slower (P<.05) than steers fed 0.35% Ca. Feed efficiency was also improved (P<.05) when steers were fed the lower level of Ca.

Bone density of the first phalanx bones, whether expressed as total grams of mineral or as % of carcass weight, was unaffected by P level (Table 3). Rib bone area and breaking strength, when expressed as area under curve, peak force in lbs or time before breaking, also were unaffected by P intake. Steers fed the higher percent Ca did not have greater phalanx bone density or rib bone area. Ribs from steers fed 0.70% Ca required greater (P<.10) peak force but less time to break than steers fed 0.35% Ca.

In previous studies, levels of Ca in excess of requirement have resulted in lower intakes due to limestone's palatability problems. While intakes were depressed with the higher level of Ca, gains were similar, resulting in improved efficiency. The efficiency improvement has been attributed to a buffering effect, causing less acidosis-related problems with elevated levels of Ca. In this study, the higher Ca decreased both gains and efficiency. Since the finisher contained 22.5% corn bran, the diet contained less starch than a typical 85 % corn diet. With less starch fed, acidosis problems may be reduced and any benefits from Ca buffering would not be evident as the results suggest. Decreased gains at the high level of Ca may be attributable to less energy being used for gain, since limestone replaced DRC, and the slightly lower intake would presumably suggest less energy was available for gain once the maintenance requirement was met.

Previous studies have suggested the Ca:P ratio is insignificant for beef cattle if between 1:1 and 7:1. These results support that conclusion, since there was no interaction shown between Ca and P levels with ratios between 1:1 and 5:1. Additionally, P required for maximal gain and bone maintenance for finishing yearlings is equal to or less than 0.14 % of dietary DM or 15.9 grams/day. The 1996 NRC overestimates P required for these animals, and predicts 0.22 % of diet DM or 22.6 g/d P intake. However, high Ca levels may depress performance if limestone is used and byproducts are fed to minimize acidosis-related problems.

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[1]Galen Erickson, graduate student; Mark Klemesrud, research technician; Todd Milton, Assistant Professor, Terry Klopfenstein, Professor, Animal Science, Lincoln.

Use of the NRC Model for Predicting Nutrient Balances of Finishing Cattle

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Rob McCoy
Drew Shain
Todd Milton
Dennis Brink
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The NRC Model is a useful tool for predicting degradable intake protein and metabolizable protein supply, requirement, and balance for feedlot cattle when accurate estimates of intake and protein degradability are available.

Summary

Trials conducted at the University of Nebraska's Research Feedlot were used to validate the NRC Beef Cattle Nutrient Requirements Model. Guidelines were developed for nutrient values for feedstuffs commonly fed in Nebraska feedlots. Generally, the NRC model predicted DIP and MP balances which were in agreement with performance data. The NRC Model generally underpredicted feed intake. The NRC model correctly predicted DIP deficiencies in dry-rolled corn diets which did not contain supplemental degradable protein. The effective NDF level of wet corn gluten feed appears to be higher than that of dry-rolled corn. The NRC model is a useful tool for predicting DIP and MP balances for finishing

cattle when accurate estimates of protein degradabilities and intake are available.

Introduction

Recently, the National Research Council (NRC) released the latest version of the Nutrient Requirements of Beef Cattle. One of the most significant changes is the move from expressing protein requirements on a crude protein (CP) basis to a system which uses degraded intake protein (DIP) and metabolizable protein (MP). Protein degraded in the rumen and available for use by the rumen microbes is referred to as DIP. MP is the protein utilized by the host animal and is the sum of the digestible bacterial protein produced in the rumen and the digestible undegraded intake protein (UIP) from the feedstuffs consumed. While crude protein systems incorrectly assume all feedstuffs have similar ruminal CP degrabilities, the NRC Model allows the user to enter CP degradabilities for each feedstuff in the ration.

In order for the NRC model to accurately predict nutrient supply to the animal, accurate estimates of digestibility, intake and ruminal protein degradability are necessary. Our objectives were to: 1) report protein degradabilities for feedstuffs commonly used in Nebraska; 2) use research trials previously conducted at University of Nebraska research facilities to validate the use of the NRC Model; and 3) present guidelines for successful use of the NRC Model for finishing cattle.

Procedure

Research trials previously conducted at the University of Nebraska Agricultural Research and Development Center near Mead, Nebraska were used as validation data sets. Diet composition, intake and performance data from each respective trial were used as inputs for the NRC model in order to predict NE_m, DIP and MP supply, requirement and balance for various diets. For complete details regarding diets and cattle management for each trial, refer to previous Nebraska Beef Reports, which are referenced in the discussion of each respective trial.

Results

Table 1 shows suggested model inputs for effective NDF (eNDF), TDN, CP and ruminal protein degradability of several feedstuffs commonly fed in Nebraska feedlots. The eNDF level is important because the model uses it to predict a diet's ruminal pH. The predicted pH is used by the model to calculate microbial efficiency, which impacts the DIP requirement and MP supply. Low ruminal pH reduces microbial efficiency because the microbial population expends energy on maintaining internal ion concentrations rather than using the energy for growth, reducing the DIP requirement and MP supply.

Table 2 shows the effect of urea level on dry matter intake, gain and feed efficiency, as well as DIP and MP supply, requirement and balance for

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Table 1. Suggested values for feedstuffs commonly used by Nebraska feedlots.

	eNDF	TDN	CP	DIP
Grains				
High-moisture corn	0	93	8.4	60
Dry corn	0	88	8.45	40
Rolled sorghum grain	0	79	10.5	40
Byproducts				
Distillers solubles (dry milling)	0	88	28	80
Distillers solubles/steep liquor (wet milling)	0	88	36	80
Wet corn gluten feed	18	88	22	75
Sorghum distillers grains + solubles (wet)	18	96	34	40
Corn distillers grains + solubles (wet)	18	106	30	40
Protein meals				
Soybean meal	0	88	49.9	70
Feather meal	0	90	85.8	30
Blood meal	0	90	93.8	25
Harvested forages				
Corn silage	71	75	7.4	75
Alfalfa hay	100	60	16	82
Brome hay, mid bloom	100	66	14.4	84
Alfalfa hay, early vegetative	100	74	30	93
Alfalfa hay, late vegetative	100	67	20.3	85
Prairie hay[a]	100	49	6.8	80
Prairie hay[a]	100	53	7.7	75

[a]Match to nearest CP value.

Table 2. Effect of urea level on intake, gain, feed efficiency and DIP and MP supply, requirement and balance for finishing yearlings.

	Treatment			
	CP Level	9.7	12	13.5	15
Item	Urea Level	0	0.88	1.34	1.96
Dry matter intake, lb/day		25.57	26.17	25.72	25.93
Daily gain, lb[a]		2.67	2.91	2.86	2.94
Feed/gain[bc]		9.56	8.99	8.98	8.84
Predicted dry matter intake, lb/day		22.1	22.3	22.0	23.7
DIP supply, g		484	763	928	1123
DIP requirement, g		795	823	802	807
DIP balance, g		-311	-60	126	316
MP supply, g		944	974	948	954
MP requirement, g		724	753	741	758
MP balance, g		220	221	207	196

[a]No urea versus urea treatments, P<.01.
[b]No urea versus urea treatments, P<.05.
[c]Feed/gain was analyzed as gain/feed. Feed/gain is the reciprocal of gain/feed.

finishing yearlings fed a dry rolled corn-based finishing diet (1995 Nebraska Beef Report, pp. 21-22). Gain and feed efficiency were improved by providing supplemental DIP from urea. The NRC model predicted a slight DIP deficiency with the 12% CP level. However, no improvements in gain or efficiency were noted when diets containing more than 12% CP were fed. Metabolizable protein balances were positive for all diets, but the NRC model assumes DIP deficiencies will be met when it calculates MP supply. Due to the deficiencies in DIP, the MP supply with the 9.7% CP diet would be reduced by 199 g assuming no additional recycling. This would still be adequate MP for the midpoint of the trial. The cattle may have been deficient in MP during the first half of the trial, although the model does not predict a deficiency. Deficiencies in DIP can also reduce ruminal fermentation of carbohydrate, reducing energy available to the animal. Because the ruminant has the ability to recycle nitrogen, excess undegraded intake protein (UIP) in the diet may substitute to some degree for deficiencies in DIP. This may explain why no advantages in finishing performance were noted diets contained greater than 12% CP. Excess DIP, however, cannot substitute for deficiencies in MP.

The NRC model underestimated dry matter intake of these finishing yearlings by approximately 3 lbs (Table 2). Accurate estimates of intake are a critical input for successful use of the model. In general, the NRC model intake prediction equations tend to underestimate intake for finishing yearlings, as well as that of calf-feds, early in the finishing period. When no information about historical performance is available for a particular situation, we recommend using dry matter intakes equal to 3.0% of body weight when the finisher diet is first fed for both finishing calves and yearlings. This will be equal to approximately 20 pounds of dry matter intake for finishing calves and 25 pounds for finishing yearlings. Intakes don't vary markedly on the finisher diet from early to late in the feeding period. However, if historical intake estimates for a particular class of cattle are available, use them instead.

Table 3. Effect of supplemental protein source on dry matter intake, gain and feed efficiency and DIP and MP supply, requirement and balance for finishing calves.

Finishing Period			
	Treatment[a]		
Item	U	SBM/U	FM/U
Dry matter intake, lb/day	19.62	19.43	19.29
Daily gain[b], lb	2.88	2.97	2.97
Feed/gain[cd]	6.80	6.54	6.49
Predicted dry matter intake lb/day	19.99	19.35	19.45
DIP supply	640	600	590
DIP requirement	640	630	630
DIP balance	0	-30	-40
MP supply	760	860	840
MP requirement	720	720	720
MP balance	40	140	120
First 63 Days			
Predicted dry matter intake (lb/day)	17.01	16.81	16.99
Actual dry matter intake (lb/day)	21.20	20.60	20.96
DIP supply (g/day)	689	658	638
DIP requirement (g/day)	665	653	657
DIP balance (g/day)	24	5	-19
MP supply (g/day)	787	882	875
MP requirement (g/day)	834	833	828
MP balance (g/day)	-47	49	47

[a]U=urea, SBM=soybean meal, FM=feather meal.
[b]U vs average of SBM/U and FM/U (P<.10).
[c]U vs average of SBM/U and FM/U (P<.05).
[d]Feed/gain analyzed as gain/feed. Feed/gain is the reciprocal of gain/feed.

Table 4. Effect of energy and protein source on finishing performance and predicted DM intake, and DIP and MP supply, requirement and balance for finishing calves.

	Treatment[a]			
Item	DRC/Urea	DRC/EP	WCGF	WCGF/EP
DM intake[b], lb/day	22.73	22.52	21.67	21.97
Daily gain, lb	3.81	3.83	3.72	3.80
Feed/gain[c]	5.96	5.88	5.83	5.78
Predicted DM intake, lb/day	18.37	17.89	17.87	17.94
MP supply, g/day	867	939	848	938
MP requirement, g/day	817	820	809	816
MP balance, g/day	50	119	39	122
DIP supply, g/day	732	729	814	829
DIP requirement, g/day	749	739	834	842
DIP balance, g/day	-17	-10	-20	-13

[a]DRC=dry rolled corn, EP=escape protein, WCGF=wet corn gluten feed.
[b]DRC vs WCGF (P<.05)
[c]Feed/gain analyzed as gain/feed. Feed/gain is the reciprocal of gain/feed.

Table 3 shows the effect of supplemental source of CP on finishing performance and DIP and MP supply, requirement and balance for finishing calves. Control and high-lysine corn were dry rolled and supplemented with urea, soybean meal or feather meal (1994 Nebraska Beef Report, pp. 30-32). No protein supplement by corn type interactions were detected (P>.15) so data were pooled across corn type. Over the entire trial, the NRC model predicted intake similar to actual dry matter intake. Daily gain and feed efficiency were improved with the addition of soybean meal and feather meal compared to urea alone. Over the entire trial, the NRC model predicted MP was adequate for all treatments, while DIP was slightly deficient for the soybean meal and feather meal supplemented diets. It is possible for excess UIP in the diet to meet DIP deficiencies through recycling. For the first 63 days of the finishing period, the NRC model pre-

Table 5. Suggested inputs and guidelines for use of the 1996 NRC model.

1. **Units and Levels Section.**
   Use only Level 1, unless rates of digestion of all feed fractions are known.
2. **Animal Section.**
   Remember that your choice of breed affects maintenance energy requirements.
   Bos indicus cattle have lower NE_m requirements, while dairy and dual purpose breeds have higher requirements. This is discussed in detail in the textbook accompanying the NRC Model.
3. **Management Section.**
   A. **Microbial Yield.** With growing and finishing diets the model uses the effective NDF values of the feedstuffs to predict a ruminal pH, which is used to calculate microbial yield or efficiency. Use effective NDF values listed in Table 1. Do not adjust the microbial yield in the model for cattle fed finishing diets because the model will do this automatically using effective NDF.
   B. **Diet NE_m and NE_g Adjusters.** Use these to adjust performance predicted by the NRC Model to match the actual closeout performance or pen projected performance. The model may calculate unrealistically high feed efficiency and ADG for calves early in the finishing period. We suggest using the following adjustments for Diet NE_m and NE_g. For every 100 lb from the midpoint weight, change both NE_m and NE_g adjusters by 6 percentage units. For example, if calves are being fed from 600 lb to 1200 lb, the midpoint is 900 lb. When the calves weigh 700 lb, set the NE_m and NE_g adjusters at 88. At 1100 lb the adjusters would be 112. Use this as a guideline only.
   C. **Additive.** Select the proper implant and additive used. The model will adjust predicted DMI and NE_m requirements appropriately for the use of ionophores and implants.
   D. Do not use the **On Pasture** feature for growing and finishing cattle which are in a pen-fed situation. This feature increases NE_m requirements to account for the impact of grazing activity on nutrient requirements.
4. **Environment Section.**
   A. **Temperature.** Because of daily fluctuations in temperature, it is difficult to state a temperature which the cattle are subjected to. Interactions also exist with other environmental factors which are discussed below. We recommend using long term average temperatures for a given month or season at a given location.
   B. **Wind speed.** Caution is needed when using this feature. Because cattle behavior is impacted by wind speed, cattle are not subjected to reported wind speeds. Wind speed is generally measured by anemometers positioned 10' above ground. Cattle are seldom subjected to these wind speeds because they will find ways to minimize the effect of wind on them. We recommend using wind speeds of less than 5 miles per hour in most cases.
   C. **Hair Depth.** Use .25 inches in the summer and .5 inches for winter coats.
   D. **Hide.** Use 1 (thin hide) for Bos indicus and dairy breed types, and 2 (average) or 3 (thick) for most English and Continental breeds.
5. **Feeds Section.**
   A. Use the **Feed Library** (a feature separate from the model) to make global changes to feedstuff composition. Use the **Feed Composition** feature to make feed composition changes specific to a ration or problem (composition changes made in this manner will be specific to that input file only).
   B. When estimates of feed intake are unavailable or unknown, use the NRC estimated intake as a guideline. As a general guideline, use 3% of body weight when the finisher diet is first fed as an estimate of feeding period intake for calves and yearlings.

dicted the urea diet was deficient in MP while the soybean meal and feather meal diets were adequate. Metabolizable protein requirement is higher during the early part of the finishing period because gains are higher. We believe the response to escape protein occurred in the first two months of the feeding period, when relative protein requirements of calves would be higher.

Table 4 shows the effect of energy and protein sources on performance and DIP and MP balances for finishing calves. Dry-rolled corn and wet corn gluten feed were fed with and without supplemental UIP in a 2 x 2 factorial treatment design. Details on calf and yearling feeding management are found in the 1995 Nebraska Beef Report (pp. 28-30). No differences in gain or efficiency were noted for either energy or protein source. The NRC model predicted each diet was slightly deficient in DIP but had adequate MP. The NRC model underpredicted intake by approximately 4 lbs. Because of the higher protein degradability of wet corn gluten feed, a deficiency in MP may be expected when feeding it. However, metabolism research (1997 Nebraska Beef Report, pp. 61-65) indicated ruminal pH is higher when wet corn gluten feed is included in the diet at the expense of dry rolled corn. The NRC model uses the eNDF of the diet to adjust microbial efficiency downward when eNDF is less than 20%. For diets with greater than 20% eNDF, the model makes no adjustment. For each 1% decrease in eNDF from 20%, the model decreases microbial efficiency by 0.29% (beginning at 13%). For example, if the diet contained 5% eNDF (common with a grain based finishing diet containing 7.5% roughage), microbial efficiency would be reduced by 4.35% and would be equal to 8.65% [13%-4.35%]. Biologically, the reason for this efficiency reduction is related to microbial physiology in the rumen. When pH drops, the microbial population spends more energy for maintenance rather than growth. Therefore, microbial protein production is reduced, resulting in decreases in MP supply, as well as decreases in the amount of DIP required by the microbes.

Table 5 lists the guidelines recommended for successful use of the model with growing and finishing cattle. Like any computer program, the model is highly dependent on user-given inputs. Key areas when considering inputs are: 1) Microbial yield; 2) Diet NE_m and NE_g adjusters; and 3) the Environment section. For finishing diets, leave 13% as the default value for microbial yield. The model will automatically calculate the predicted yield. Use the diet NE_m and NE_g adjusters to adjust performance of the cattle to match projected or actual gain and feed efficiency. The model is very sensitive to wind speed and temperature inputs. Consequently, the predicted energy requirement can fluctuate a great deal depending on environmental inputs.

The NRC model is useful for predicting DIP and MP balance when realistic estimates of intake and ruminal protein degradability are available. Without these estimates however, the user may not get accurate predictions. In general the NRC model tended to underpredict DM intake of both finishing calves and yearlings. If historical estimates of intakes for a particular class of cattle are known, they should be used for NRC model calculations.

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Evaluation of 1996 NRC for Protein and Phosphorus Requirements of Finishing Cattle

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The 1996 NRC computer model does not under-predict the protein and phosphorus requirement of finishing calves and yearlings

Summary

Two trials were conducted to evaluate the 1996 Beef NRC computer model for protein and phosphorus requirements of feedlot cattle. The control ration was formulated for the same levels of crude protein (13.5%) and phosphorus (0.35%) in both trials; however, supplemental protein was from urea in Trial 1 and urea, feather meal and blood meal in Trial 2. The balanced ration was formulated utilizing the 1996 NRC. The balanced ration was changed to effectively meet the changing requirements for DIP, UIP and P. In Trial 1, gains and efficiencies were similar between treatments; however, DMI was lower with cattle fed the balanced ration. In Trial 2, animal performance was unaffected by dietary treatment. These results indicate that the 1996 NRC model does not underpredict finishing steer protein and P requirements.

Introduction

In 1996, the NRC beef committee updated the requirements for beef cattle. There were numerous advancements adopted, including a computer model and a metabolizable protein (MP) system. The MP system accounts for two different requirements, microbial and animal, which must be met to optimize performance. Each feedstuff is degraded to various degrees in the rumen. For example, high-moisture corn (HMC) is 8 - 10% protein which is 60 % degradable in the rumen, whereas dry-rolled corn (DRC) contains the same amount of crude protein but is only 40 % degradable by the ruminal microbes.

Calves have a higher MP requirement than yearlings. At the same time, calves require less MP at the end of the finishing period than at the beginning. Therefore, if the diet is to meet the requirements, the diet must change both between yearlings and calves and within time on feed. This is commonly referred to as "phase feeding." Understanding this system allows nutritionists to more effectively optimize performance without overfeeding.

Protein requirement can be divided into two segments, degradable intake protein (DIP), which meets the microbial requirement and undegradable intake protein (UIP), which bypasses the rumen and is used by the animal at the small intestine in addition to microbial protein leaving the rumen. Our objective was to evaluate the 1996 NRC guidelines with both calves and yearlings and balance a ration to meet the DIP and UIP requirements while minimizing the overfeeding of protein and phosphorus.

Procedure

In Trial 1, 96 crossbred, yearling steers (BW = 656 lb, age = 14 mos) were randomly assigned (8 hd/pen) to either the control ration or the balanced ration. Steers were on feed 147 days from May 10 to October 4, 1996 and implanted with Revalor-S on day 0 and day 84. Cattle were adapted to the finisher diet with four step diets containing 45, 35, 25 and 15 % alfalfa hay fed for 3, 4, 7 and 7 days respectively. The control ration (Table 1) was formulated to provide 13.5 % crude protein and 0.35 % phosphorus (P), with all supplemental protein from urea. The balanced ration was formulated using the 1996 NRC model (predicted final wt = 1200, 50 % Br X 50 % Cont, ADG = 3.7 lbs/d) to meet and not exceed the DIP requirement and minimize excess UIP in the diet. Since protein from HMC is more degradable in the rumen, and the requirement for DIP as a portion of MP required is greater for yearlings, the DRC was replaced with HMC in the balanced ration to minimize overfeeding of UIP. Likewise since corn contains 0.25 to 0.30% P, and the requirement is 0.23 % P for 750 lb yearlings, the balanced ration contained enough corn bran (0.10 % P) to meet, but not exceed, the P requirement predicted by the NRC model. Since the P requirement changes with days on feed, various levels of corn bran were fed for 28, 28 and 58 days, respectively.

In Trial 2, 96 crossbred steer calves (BW = 541 lb, age = 8 mos) were randomly assigned (8 hd/pen) and fed for 193 days from November 8, 1996 to May 20,1997. Steers were implanted on day 1 and day 97 with Revalor-S. Cattle were adapted to finisher diets (7.5 % alfalfa) similar to Trial 1 except each step ration was fed for 7 days. The control ration was formulated to provide 0.35 % P and 13.5 % crude protein just as Trial 1; however, supplemental protein was from urea, 1.4 % feather meal and 0.2 % blood meal on a DM-basis, supplemented for escape protein throughout the 193 days. The balanced ration was formulated similarly to Trial 1 (predicted final wt = 1200 lbs, 50 % Br X 50 % Cont, ADG = 3.9 lbs/d). Table 1, however, illustrates the change in requirement with calves as predicted by the NRC. The first seven finisher diets were fed for 14 days each and finisher 8 was fed until slaughter. Since calves initially require less DIP as a percentage of total protein fed, DRC was used and gradually switched over to HMC by

Table 1. Diet composition (% of DM).

	Trial I — Yearlings				Trial II — Calves								
Item[a]	Contr.	Fin 1	Fin 2	Fin 3	Contr.	Fin 1	Fin 2	Fin 3	Fin 4	Fin 5	Fin 6	Fin 7	Fin 8
DRC	81.3				82.5	82.5	82.5	82.5	82.5	59.5	35.0	4.5	
HMC		67.4	64.6	61.4						16.5	36.5	61.0	57.5
C.bran		17.2	19.9	23.1						6.5	11.0	17.0	25.0
Liq-32	6.2				5.0								
molasses						5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
fat		3.0	3.0	3.0									
Alfalfa	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5
Suppl.	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
urea	0.52	0.76	0.76	0.76	0.29	0.83	0.88	0.91	0.96	0.87	0.75	0.62	0.60
FM[b]					1.40	1.60	1.15	0.75	0.18				
BM[c]					0.20	0.20	0.14	0.10	0.02				
dical P	0.48				0.47	0.10	0.04						
CP (%)	*13.6*	*11.2*	*11.9*	*11.5*	*13.4*	*12.7*	*12.4*	*12.1*	*11.7*	*11.5*	*11.2*	*10.8*	*10.9*
UIP (%)[d]	*4.48*	*3.67*	*3.67*	*3.67*	*5.16*	*5.51*	*5.23*	*4.99*	*4.64*	*4.11*	*3.68*	*3.11*	*3.02*
P (%)	*0.34*	*0.24*	*0.24*	*0.22*	*0.35*	*0.26*	*0.25*	*0.24*	*0.24*	*0.23*	*0.22*	*0.21*	*0.20*

[a]Dry-rolled corn, high-moisture corn, corn bran and liquid supplement.
[b]Feather meal.
[c]Blood meal.
[d]Balanced finishers for Trial 1 unavoidably contained more UIP than required.

finisher 7. The P requirement also decreases with increasing weight of the animal, so HMC was gradually replaced with corn bran to prevent overfeeding of P.

Initial weights used for both trials were an average of two consecutive weights at the initiation of the trial following a 5-day limit-feeding period. At slaughter, hot carcass weights and liver scores were recorded. Quality grade, yield grade and fat thickness at the 12th rib were recorded following a 48 hr. chill. Final weights were calculated as hot carcass weight divided by a common dressing percentage (62).

Results

In Trial 1, steers fed the balanced ration had lower (P<.01) DMI than steers fed the control ration (Table 2). Gains and feed efficiency of steers fed the balanced ration were similar to control steers, despite feeding a diet that was 2% units lower in crude protein and contained no supplemental P. Carcass traits were also unaffected by dietary treatment.

In Trial 2, calves fed the balanced ration had similar DMI, ADG and feed efficiency as control animals. Initially, calves on the balanced ration were fed more escape protein (UIP) and gains were numerically greater than control steers. Dry matter intake did vary between treatments during each finishing phase.

Results indicate the 1996 NRC requirement system is an effective tool to manipulate protein feeding regimens in the feedlot without compromising animal performance. Additionally, "phase feeding" matches dietary supply with changes in animal nutrient requirements with time on feed. However, this system does require formulation of multiple finisher rations, increasing feed delivery management and supplement inventory.

Phosphorus is an expensive nutrient and is not as critical to supplement (1998 Beef Report, pp 78) in feedlot diets as is commonly believed, especially since energy sources are normally greater than 0.25 % P. Animal performance for both calves and yearlings was unaffected by decreasing P levels below 0.25 %. Therefore, we conclude P supplementation is unnecessary because of the monetary and potential environmental cost.

Table 2. Performance of finishing yearlings and calves.

	Trial 1 — Yearlings				Trial II — Calves			
Item	Control	Balanced	SE	P<	Control	Balanced	SE	P<
Initial wt.	652	660	2.8	.12	539	542	.63	.01
Final wt.	1249	1249	9.8	.99	1245	1247	10.8	.59
DM Intake	26.2	25.0	.20	.01	20.6	20.5	.25	.77
ADG	4.06	4.01	.06	.60	3.66	3.65	.06	.74
Feed/gain [a]	6.45	6.21		.15	5.72	5.64		.61
HCW [b]	774	774	6.1	.99	769	774	6.7	.59
QG [c]	18.5	18.1	.25	.30	18.5	18.3	.10	.17
Fat depth	0.52	0.51	.01	.70	0.55	0.53	.01	.14

[a]Analyzed as gain to feed, the reciprocal of feed to gain.
[b]Hot carcass weight.
[c]Quality grade where 18 = Select+, 19 = Choice-.

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Nutrient Balance of Nitrogen, Organic Matter, Phosphorus and Sulfur in the Feedlot

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Decreasing protein and phosphorus intake to requirements predicted by 1996 NRC maintained animal performance, decreased nitrogen and phosphorus excretion, and improved waste characteristics.

Summary

Ninety-six crossbred yearling steers (656 lb) were assigned to either control (CON) or balanced (BAL) treatments. Steers were fed for 135 days in 12 waste-management pens with runoff collection basins. Control diet consisted of a DRC, 7.5 % roughage finisher formulated for 13.5 % protein and 0.35 % phosphorus. Balanced diet was formulated using the 1996 NRC model to meet the animal's protein (11.5%) and phosphorus (0.22%) requirements. Gains were unaffected and feed efficiency tended to improve by feeding the BAL diet. Nitrogen and P excretion were lower with BAL steers compared with CON steers. Consequently, the manure's N:P ratio was improved relative to crop needs from 1.9:1 to 3:1 for CON and BAL treatments respectively. Feeding at the animal's requirement for protein and P decreases N and P excretion and improves waste characteristics without compromising animal performance.

Introduction

With the concentration of the feedlot industry into fewer acres and fewer producers, waste management is becoming an increasingly important issue. Feedlot design has advanced to handle the nutrient concentration in these feedlots, particularly surface runoff and leaching. From a cost perspective, minimizing total manure production and decreasing removal time is advantageous. Since manure should be used as a crop fertilizer in feedlot areas, concentration of nitrogen (N) and phosphorus (P) is critical, as crops require a 5:1 N to P ratio.

When manure is used as a fertilizer, either excess P is applied to the land base or extra N needs to be applied to optimize crop yields, since manure typically contains a 2:1 N to P ratio or less. The reason the ratio is typically much lower than 5:1 is partially due to 50 - 70 % of the N volatilizing from the pen after excretion. Phosphorus does not volatilize. Increasing N or decreasing P will add value to the manure relative to crop needs. From a land base requirement perspective, decreasing total N and P excretion would be the most advantageous.

In 1996, the NRC beef committee adopted the metabolizable protein system for evaluation of animal requirements. This system allows nutritionists to match dietary inputs with requirements more accurately than the previous crude protein system.

The objective of this study was to determine effects of minimizing overfeeding of protein and phosphorus on waste management in the feedlot.

Procedure

Ninety-six crossbred yearlings (BW = 656 lb) were used in 12 waste management pens (8 hd/pen). Soil in pens was core sampled (0 to 6 inches) before the trial to estimate nutrient concentration on the pen surface. The animals were then fed for 135 days and pens cleaned after the trial. Manure was sampled during removal and pen soil samples collected to estimate nutrient balance. Soil sampling allows adjustment for inevitable cleaning differences between pens. The pens also contained runoff collection basins to determine total runoff from pens on different treatments. Due to pen design, two pens drain into one pond; therefore dietary treatments were assigned in blocks of two pens. All samples including feed and feed refusals were analyzed for N, OM, P and S.

Two dietary treatments included the control ration (CON), 13.5 % protein and 0.354 % P, and balanced ration (BAL) which minimized protein and P fed to meet, and not exceed, the requirements predicted by the 1996 NRC, 11.5 % protein and 0.22 % P. Control ration included (DM-basis): 81.3 % dry-rolled corn (DRC), 7.5 % alfalfa, 6.2 % molasses with urea and 5.0 % dry supplement. Balanced ration included: 61.4 to 67.4 % high-moisture corn (HMC), 17.2 to 23.1 % corn bran, 7.5 % alfalfa, 3.0 % fat and 5.0 % supplement. Since HMC replaced DRC in the balanced ration, more protein was rumen degradable; therefore less urea was needed to meet the degradable intake protein (DIP) requirement. Corn bran was also added to decrease the P level to the predicted requirement. Three rations were fed in steps with increasing levels of corn bran since the P required decreases with time on feed.

Results

Animal weights, gains and efficiencies were similar between CON and BAL steers (Table 1). Dry matter intake and organic matter (OM) intake were greater ($P<.01$) for CON fed steers. Since BAL contained corn bran to lower P intake, OM excretion was increased

Table 1. Performance of yearling steers by treatment.

	Treatment			
Item	Control	Balanced	SE	P<
Initial weight	652	660	2.8	.12
Final weight	1249	1249	9.8	.99
DM Intake	26.2	25.0	.2	.01
ADG	4.06	4.01	.06	.60
Feed/gain[a]	6.45	6.21		.15

[a]Analyzed as gain to feed, the reciprocal of feed to gain.

Table 2. Organic matter (OM) and nitrogen (N) balance.

	Organic matter				Nitrogen			
Item	Control	Balanced	SE	P <	Control	Balanced	SE	P <
(lbs/hd/day)								
Input	25.2	23.3	.21	.01	0.56	0.47	.004	.001
Retention[a]					0.06	0.06	.0005	.26
Excretion[b,c]	5.15	7.16	.06	.001	0.50	0.42	.004	.001
(lbs/hd)								
Excreted	703	941	7.8	.001	66.3	54.6	.56	.001
Manure	242	404	9.6	.001	12.6	19.7	.52	.001
Soil[d]	7.9	-86	22.6	.05	2.07	-2.83	1.66	.10
Runoff	61	47	6.2	.20	2.47	2.07	.29	.40
Volatilized[e]	393	576	28.8	.01	49.2	35.7	1.77	.01
% volatilized	56	61			74	65		

[a]N retention based on ADG, NRC equation for retained energy and retained protein.
[b]OM excretion calculated as 20.7 % indigestibility for control and 29.9 % for balanced.
[c]N excretion calculated as intake minus retention.
[d]Soil value is from core balance on pen surface before and after trial; negative values suggest removal of nutrient present before trial.
[e]Volatilized calculated as excretion minus manure minus soil minus runoff.

Table 3. Phosphorus (P) and sulfur (S) balance.

	Phosphorus				Sulfur			
Item	Control	Balanced	SE	P <	Control	Balanced	SE	P <
(lbs/hd)								
Intake	12.52	7.90	.08	.001	6.46	5.23	.04	.001
Retention[a,b]	2.05	2.03	.02	.30	0.51	0.50	.004	.27
Excreted[c]	10.47	5.87	.07	.001	5.96	4.73	.04	.001
Manure	6.77	6.49	.28	.50	3.41	5.48	.29	.01
Soil[d]	-1.25	-2.99	.78	.20	-0.13	-3.61	1.17	.10
Runoff	1.75	1.49	.08	.10	2.37	2.33	.24	.90
Difference[e]	3.21	0.89	.86	.12	0.30	0.53	1.22	.90

[a]P retention based on NRC retained protein, 3.9 g / 100 g protein gain.
[b]S retention based on NRC requirement for sulfur amino acids, 4 g SAA / 100 g protein gain.
[c]P and S excretion calculated as intake minus retention.
[d]Soil value is from core balance on pen surface before and after trial; negative values suggest removal of nutrient present before trial.
[e]P and S difference calculated as excretion minus manure minus soil minus runoff.

(P<.01) compared with CON (Table 2). Organic matter removed in manure was increased in BAL pens, due to more excreted and more removed from pen surface. Estimates of OM volatilization or loss was 393 lbs/hd for CON and 576 lbs/hd for BAL. When expressed as percent volatilization, approximately the same amount of OM was lost from each treatment, 56 % and 61 % for CON and BAL pens, respectively.

Nitrogen intake was reduced with BAL treatment (Table 2). Since animal performance was similar, retained protein and N were similar, leading to less N excretion by BAL steers than CON steers. More N was removed from BAL pens, even though N excretion was less. Since more OM was excreted due to the corn bran, more N was trapped on the pen surface with the BAL treatment as compared to CON. This is shown in percentage of excreted N volatilized as ammonia, which was 65.4% for BAL pens compared to 74.2 % for CON pens.

Phosphorus intake was reduced from 12.5 lbs/hd to 7.9 lbs/hd for the 135-day trial for both diets (Table 3). The reduced intake leads directly to a reduction in P excretion, since retention is dependent on retained protein and gain. Similar amounts of P were removed at cleaning from both diets. The BAL cattle excreted less P, suggesting P removed in manure should also be less; however, more P was removed from the pen than was present at the start of the trial, illustrated by the soil core balance. Since P is not volatile, the P not accounted for suggests discrepancies exist between samples and what is either on the soil surface of the pen or in the manure at cleaning.

Sulfur intake and excretion were reduced (P<.01) for BAL steers compared to CON (Table 3). However, more S was removed in the manure than was excreted in the BAL pens. The core balances suggest more OM, N, P and S were removed at cleaning than were present before the trial in BAL pens. Less than 5 % of excreted S in CON pens and 11 % in BAL pens was presumably volatilized, suggesting total reduced sulfur and other volatile sulfur compounds are not significant.

Reducing protein and phosphorus levels maintained animal performance and decreased N and P excretion. The increase in OM excretion did allow more OM and N to be removed even though N excretion was reduced. The N:P ratio in the manure was increased from 1.9:1 to 3:1 for CON and BAL treatments respectively.

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Nutrient Balance on Nebraska Feedlots

Rick Koelsch
Gary Lesoing[1]

Nitrogen and phosphorus inputs in excess of managed outputs on many Nebraska feedlots is a driving force behind the environmental challenges faced by the industry.

Summary

A balance between the nutrient inputs and the managed nutrient outputs balance was constructed for 16 Nebraska feedlots to provide insight to potential environmental risks. Substantial nitrogen and phosphorus imbalances were observed for many participating feedlots. Size of the livestock operation and the degree of integration of livestock with a cropping operations provided only limited explanation concerning nutrient balance variations observed among the feedlots. Substantially improved nutrient balances were achieved by those feedlots marketing manure nutrients to off-farm customers. A "sustainable" nutrient balance appears possible for larger feedlots actively marketing manure nutrients.

Introduction

Nitrogen and phosphorus losses to surface and groundwater are critical water quality issues associated with livestock manure. In Nebraska, livestock and poultry excrete approximately 320,000,000 pounds of nitrogen and 230,000,000 pounds of phosphorus annually. A 1995 GAO report to the United States Senate suggested manure was the source of 37% of all nitrogen and 65% of all phosphorus into watersheds in the central states, including Nebraska.

An underlying cause to the environmental problems associated with livestock production is the accumulation of nutrients on livestock farms. A large fraction of nutrients consumed by animals does not leave the farm as meat. Klopfenstein has previously reported yearling cattle retain only 10.4% and 18.5% of the nitrogen and phosphorus fed, respectively. Most nutrients fed to animals remain on the farm in manure.

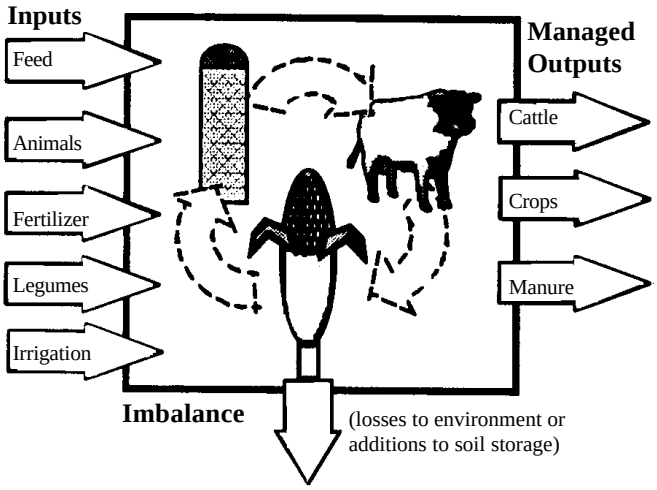

Figure 1. Balance Between Nutrient Inputs and Managed Outputs for a Feedlot.

The intent of this study is to define the nutrient balance on Nebraska livestock operations. The study also attempts to identify characteristics or management practices minimizing the accumulation of nutrients on farm.

Procedure

An accounting of nutrient inputs (purchased feed, fertilizer, animals, biologically fixed nitrogen and nitrates in irrigation water) and managed nutrient outputs (animals, crops and other products moved off-farm) was completed for 16 cattle feedlot operations (Figure 1). Changes in farm inventory were included in the analysis. The accounting period was for one year (1995 for four feedlots and 1996 for 12 feedlots). The degree of imbalance was estimated based upon differences in inputs, managed outputs and inventory changes. The calculated imbalance in nutrients can either be lost to the environment (nitrate leaching to groundwater, nitrogen in surface water runoff or ammonia volatilization) or added to soil storage mechanisms (increasing potential for phosphorus losses in surface runoff).

When available, measured nutrient concentrations values for individual feedlot nutrient inputs and outputs were used. Generally, a nutrient analysis was available for purchased feeds and marketed manure and sometimes for crops sold. Literature values were used for other nutrient inputs and outputs. Feed values from the 1996 NRC Nutrient Requirements of Beef Cattle were used for crops and feeds with no individual farm nutrient analysis.

Results

The nutrient balance is defined (Table 1) for two integrated crop and livestock operations (Farms 1 and 2) and two predominantly cattle feedlot operations (Farms 3 and 4). The magnitude of the nitrogen (41 tons to 2,180 tons per year) and phosphorus (-4 to +280 tons per year) accumulation on these four farms was significant. Farms 1 and 2 exhibited a smaller relative nitrogen imbalance (approximately 50% of inputs) and a negative or neutral phosphorus balance. Both have a substantial land base relative to the animal numbers. Farms 3 and 4 relative nutrient imbalances were larger (approximately 75% of nitrogen inputs and 60% of phosphorus inputs). The relative reliance on home-grown feeds (Farms 1

Table 1. Nitrogen and phosphorus balance for four Nebraska feedlots.[a]

	Farm 1	Farm 2	Farm 3	Farm 4
		Farm Characteristics		
Animal Units (1000 lb.)[b]:	540	3770	4330	20,650
Crop Acres Per Animal Unit:	1.7	0.4	0.0	0.1
		Nitrogen (tons/year)		
Inputs	94	130	516	2852
Managed Outputs	-46	-68	-135	-639
Inventory Change	-8	0	0	-30
N Balance ...tons	41	62	381	2,183
%	47%	48%	74%	77%
		Phosphorus (tons/year)		
Inputs	6	18	94	459
Managed Outputs	-8	-19	-37	-168
Inventory Change	-2	0	0	-9
P Balance ...tons	-4	-1	57	280
%	-98%	-7%	61%	62%

[a]This nutrient balance assumes no export of manure nutrients to off-farm customers. Any corrections to this assumption will be made in Table 3.

[b]Animal units represents the average animal capacity of a feedlot times the average animal weight divided by 1,000. A 2,000 head feedlot average capacity with an average animal weight of 950 pounds represents 1,900 animal units (2,000 X 950 / 1,000 = 1,900).

Table 2. Nutrient balance for a 4,500 head feedlot with no land base and 20,000 head feedlot with limited land base with and without off-farm marketing of manure nutrients.

	Is Marketing of Manure Nutrients To Off-Farm Customers Credited?			
	Farm 3		Farm 4	
	NO	YES	NO	YES
Nitrogen Imbalance[a]	381 t/yr. (74%)	316 t/yr. (61%)	2,183 t/yr. (77%)	1,465 t/yr. (52%)
Phosphorus Imbalance[a]	57 t/yr. (76%)	-1 t/yr. (-1%)	280 t/yr. (62%)	156 t/yr. 35%

[a]Tons of nutrient per year (percent of total nutrient inputs).

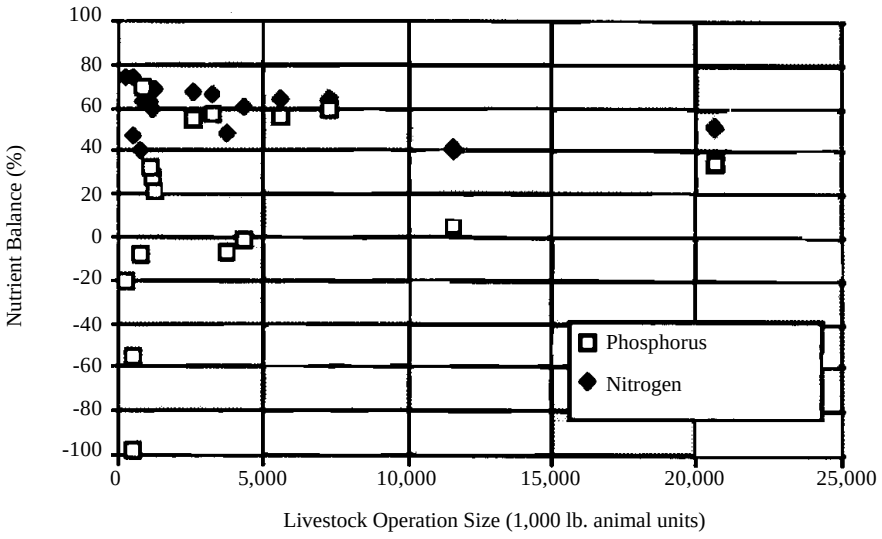

Figure 2. Nutrient balance versus size of livestock facility for 16 Nebraska feedlots.

and 2) versus purchased feeds (Farms 3 and 4) is a primary difference between these four operations.

From a water quality perspective, phosphorus balance (phosphorus is generally conserved by the manure management systems) provides a better indication as to when a sustainable nutrient balance has been achieved. Substantial losses of ammonia nitrogen by volatilization often mask when a balance is achieved. In addition, differences in volatilization losses between farms make nitrogen balance comparisons difficult.

The value of exporting manure nutrients to off-farm customers is illustrated in Table 2. As illustrated in Table 1 the nutrient balance for farms 3 and 4 assumes no export of manure nutrients from these farms. In fact, both farms actively market manure nutrients, substantially improving the nutrient balance of both. Nitrogen imbalance has been reduced, but not eliminated. The remaining nitrogen imbalance is probably due to ammonia volatilization losses to the atmosphere from the feedlot surface, manure storage (farm 4 only) and composting (farm 3 only). The phosphorus imbalance has been eliminated for farm 3 and substantially reduced for farm 4. Marketing of manure nutrients to off-farm customers appears to have achieved a sustainable nutrient balance for farm 3 and substantially improved the sustainability of farm 4.

A nutrient balance, including any transfer of manure to off-farm customers, was completed for a total of 16 cattle feedlots. The relative imbalance measured as a percentage of inputs of nitrogen and phosphorus, is summarized in Figure 2. The increasing imbalance with feedlot size observed in Table 1 is less evident in Figure 2. The largest imbalances of nitrogen were observed for several smaller feedlots. The phosphorus imbalance shows some advantage for several of the smaller feedlots. A negative phosphorus imbalance was observed for several of the smaller feedlots.

The degree of integration of crop and livestock enterprises is often

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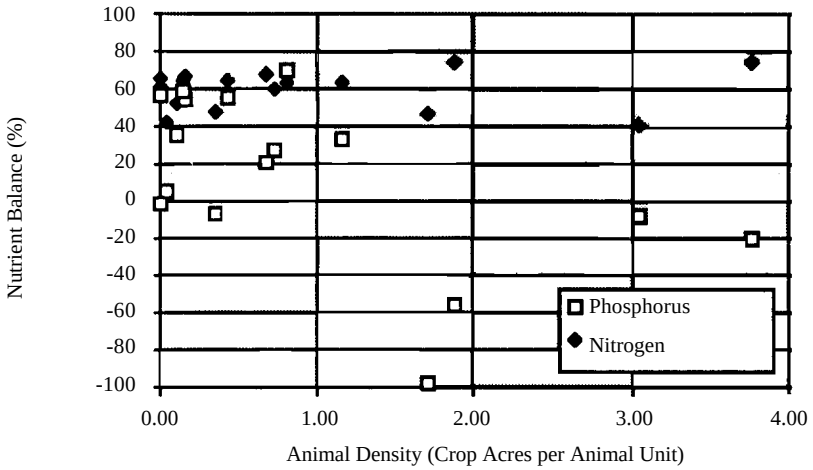

Figure 3. Nutrient balance versus crop land to animal density for 16 Nebraska feedlots.

considered an indicator of the relative potential for environmental problems. For the 16 participating farms, the nitrogen imbalance showed little change for greater animal densities (lower crop acres to animal units, Figure 3). However, the phosphorus imbalance tended to be smaller or negative for lower animal density. Farms with a significant land base have greater potential for exporting of phosphorus as crops marketed off farm.

Substantial variation in nutrient balance exists between farms. Size of livestock operation (Figure 2) and degree of integration of the livestock operation with a crop operation (Figure 3) provide only limited explanation of this variation. The role other farm characteristics or management practices play in determining the variation in nutrient balance requires additional evaluation.

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In Situ Method for Estimating Forage Protein Degradability

Ryan Mass
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A method of estimating forage protein degradability is available. In situ neutral detergent fiber nitrogen provides information necessary to calculate metabolizable protein supplied to cattle consuming forage.

Summary

Four experiments including vegetative and dormant forages tested modifications of the in situ neutral detergent fiber nitrogen (NDFN) method of estimating forage undegraded intake protein (UIP). Experiments 1, 2 and 3 tested bag size, closure, rinsing, density, and reflux conditions. None of the modifications affected in situ NDFN content. Experiment 4 compared rates of in situ NDFN digestion calculated with or without correction for undegradability. A close relationship exists between rates calculated by the two methods. Modifications make the improved in situ NDFN method a more desirable means of estimating forage UIP than the standard method.

Introduction

Metabolizable protein, the protein absorbed by the animal, equals the sum of digestible microbial protein and undegraded intake protein (UIP). Information about the ruminal degradability of dietary protein is necessary to describe the contribution it makes to both the microbial protein and UIP. Estimates of DIP and UIP are needed to calculate MP using the 1996 NRC computer software. However, few estimates of forage UIP are available.

Previous research (1997 Nebraska Beef Report, pp. 38-39) indicates neutral detergent fiber nitrogen (NDFN) is an effective method of estimating forage UIP. Our objectives were: 1) to test the effect of modifications of the method on in situ NDFN content; and 2) to examine the relationship between rates of in situ NDFN digestion calculated with or without an undegraded fraction.

Procedure

All three experiments were conducted under similar conditions. Each experiment consisted of one 16- hour incubation in a ruminally fistulated steer fed smooth bromegrass hay (8% CP) at 1.8% of body weight. Smooth bromegrass hay was incubated in every in situ bag. Four bags were incubated for each level of each factor. Estimates of UIP (mg NDFN/g sample incubated) were calculated and each experiment was analyzed separately.

Experiment 1 tested modifications of a standard in situ method. Factors tested were (standard conditions listed first): in situ bag size (10 × 20 cm vs 5 × 10 cm), degree of post-in situ hand rinsing (45 min vs 15 min), bag closure

method (rubber band around a #8 rubber stopper vs heat-sealing) and NDF method (individual refluxing of subsampled residue versus bulk refluxing of the bag containing its residue). The amount of sample incubated in the small bags was reduced (1.25 g) in order to maintain the same sample/bag surface area ratio as the large bags. The same number of rubber stoppers was placed in each mesh bag in order to ensure similar weights for each. A bulk refluxing apparatus was used for neutral detergent extraction (Ankom, Inc., Fairport, NY).

Experiment 2 was conducted using modifications tested in Experiment 1. All in situ bags were 5 × 10 cm and contained 1.25 g of sample. Bags were hand-rinsed for 15 min immediately after the incubation. The bags were heat-sealed and refluxed in neutral detergent solution in the bulk apparatus. The first factor tested a modification of the standard incubation conditions. In situ bags were incubated in the steer at two densities (20 bags/mesh bag versus 50 bags/mesh bag). Two mesh bags were incubated for each density. The second factor concerned the refluxing conditions. Use of the bulk reflux apparatus required placement of the in situ bags in a cylindrical rack. The rack consists of eight removable dishes. Each dish is capable of holding three in situ bags, for a total of 24 bags possible in each reflux. Dishes were stacked vertically and held by a metal rod. We hypothesized dish position would not affect NDFN content. The top and bottom two racks were used as the two levels of the second experimental factor. Twelve bags from each mesh bag density (three per replication) were chosen randomly and allotted randomly to either the top or bottom level of the two conducted refluxes.

Experiment 3 was conducted using modifications tested in Experiment 2. Small, heat-sealed in situ bags (5 ×10 cm) were incubated at a density of 50 bags/mesh bag. Bags contained 1.25 g of sample and were rinsed after incubation for 15 min. Bags were assigned randomly to dishes in the bulk reflux rack. Factors tested were time of NDF reflux (40 min vs 70 min) and extent of post-NDF bag rinsing (.5 L water/bag vs 1 L water/bag).

Experiment 4 was conducted to describe the effect of correcting the rate of in situ NDFN digestion (k_d) for an undegradable fraction. Three sets of forage samples were incubated together in the rumen and were collected using either esophageally or ruminally fistulated animals. Samples were collected from animals grazing the following forages (number of samples taken in parentheses): cornstalks (n=24), growing cool-season grasses (n=36) and winter native range (n=24).

All of Experiment 3's incubation modifications were used. Small bags (5 x 10 cm) were heat-sealed and incubated at a density of 50 bags/mesh bag. Bags were refluxed in neutral detergent solution in groups of 24. Each sample was incubated for 2, 12 or 96 hours. Incubations were replicated three times. Two different regression equations were calculated using the natural logarithm of mg NDFN/g of sample incubated. The slope of the regression equation equals k_d. The first k_d was calculated using bags incubated for 2 and 12 hours. This method assumes that NDFN is 100% degradable in the rumen. The second k_d was calculated by subtracting the 96 hour (96NDFN) value from both the 2 and 12 hour values. These new values were used to calculate a separate k_d. The second method assumes that the NDFN pool has reached its extent of ruminal degradation by 96 hours. Regression analysis was used to describe the relationship between the two calculations.

Results

No differences (P>.05) in 16-hour in situ NDFN content were observed between bag sizes. These results agree with previous research, which indicated forage DM digestibility is unaffected by bag size as long as the sample size/bag surface area ratio remains constant.

Rinsing in situ bags after incubation is necessary for the removal of rumen microbes from the bag and its residue. It was hypothesized that less rinsing would be necessary if NDFN was the UIP pool. Previous results indicate neutral detergent solution reflux removes attached microbes *(*1997 Nebraska Beef Report, pp. 38-39*)*. No differences (P>.05) were observed in 16-hour in situ NDFN content between bags rinsed for 45 versus 15 min. Reduction in the time spent washing makes the method more efficient and might reduce washout of small particles.

The final two factors in Experiment 1 (method of bag closure and NDF method) were included to test the efficacy of bulk refluxing of bags. It is necessary to heat-seal the bags when reflux is conducted directly on the bag and its residue. No effect (P>.05) of either factor was found. The results of Experiment 1 indicate the in situ NDFN procedure can be conducted using smaller, heat-sealed bags rinsed for 15 min after incubation and refluxed in bulk. These modifications will decrease the amount of labor needed to conduct the procedure.

The standard in situ method allows no more than 20 in situ bags in one mesh bag and up to 6 mesh bags in one ruminal incubation. However, the use of smaller bags may allow a greater mesh bag density to be used. No effect (P>.05) of mesh bag density was observed. Therefore, up to 50 in situ bags can be placed in one mesh bag and up to 300 in situ bags (5×10 cm) can be incubated in a large, fistulated bovine. Similarly, no effect (P>.05) was found for position of bags within the bulk refluxing apparatus. Bags may be allotted randomly to any dish in the bulk reflux rack without affecting NDFN content. No differences (P>.05) between reflux times or extent of post-neutral detergent extraction rinsing were observed. These results imply reflux time and extent of rinsing are not critical to the method.

Previous estimates of in situ NDFN UIP assume NDFN is 100% digestible in the rumen. However, this assumption is inconsistent with cell wall digestion models, which assume ruminally undegradable fiber exists. It is important to have an accurate estimate of k_d for a UIP fraction. The purpose of Experiment 4 was to describe the effect

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Table 1. Regression equations for correcting the rate of in situ neutral detergent fiber nitrogen (NDFN) digestion for an undegradable fraction.

Sample Set	n	Equation	r^2
Native Winter Range	24	$.468 + 1.174X + .023X^2$	.952
Cornstalks	24	$.584 + .956X + .035X^2$	.946
Vegetative Cool-Season Grasses	36	$.176 + 1.221X + .051X^2$	.804
Combination of all sets	84	$.400 + 1.227X + .028X^2$	.854

X = uncorrected rate of digestion calculated from 2 and 12-hour in situ NDFN content

of correcting the NDFN k_d for an undegraded nitrogen fraction. The amount remaining after 96 hours was assumed to be undegradable in the rumen.

Regression equations describing the effect of correcting for an undegradable UIP fraction are shown in Table 1. The equations explain a high proportion of the variation in NDFN k_d (i.e. $r^2 \geq .80$). Equations for cornstalks and native winter range were not statistically different.These results imply a close relationship exists between the two methods of calculating k_d. When equations are developed for a particular forage type at a location, corrected NDFN UIP values can be estimated from uncorrected values using the prediction equation.

In summary, the results of Experiments 1, 2, 3 and 4 imply all tested modifications can be implemented into an improved method. Such a method will save time and money relative to the standard in situ procedure and will provide more accurate estimates of forage protein degradability. Information obtained by this method will contribute to more accurate use of the 1996 NRC Beef Cattle software.

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[1]Ryan Mass and Greg Lardy, research technicians; Rick Grant, Associate Professor; and Terry Klopfenstein, Professor, Animal Science, Lincoln.

Tenderness and Retail Stability of Hydrodyne-Treated Beef

Bernadette O'Rourke
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Rose Rosario
Morse Solomon
John Long[1]

The potential exists to use an explosively-generated shock wave in water to tenderize beef. No detrimental changes to product display or shelf stability characteristics are created by the Hydrodyne process.

Summary

Detonating a small explosive within a water-filled, stainless steel tank, creates a shock wave which penetrates vacuum-packaged meat. The acoustical match between water and meat caused an immediate and significant (P<.05) reduction in shear force. After an additional 10 days of aging, no tenderness differences (P>.05) were detected. Hydrodyne created no differences in pH, sarcomere length, purge, oxidative rancidity, bacterial counts (anaerobic or aerobic) or panel color ratings for either cut. Treated samples had higher Hunter L values. The Hydrodyne process can tenderize unaged meat with no detriment to product display or shelf stability characteristics.*

Introduction

Tenderness, the primary factor determining palatability and overall consumer satisfaction of meat, is inconsistent, creating significant consumer concern. Therefore, technologies to enhance tenderness can improve both product quality and customer satisfaction.

In the Hydrodyne process, vacuum-packaged meat is placed within a stainless steel hemispherical tank and immersed in water. Detonation of a small amount of explosive within the water generates a shock wave which penetrates the meat, strikes the sides of the tank and reflects back through the meat. The entire process takes place in an encapsulated steel tank to contain the explosion and the resulting water splash.

The shock wave generates up to 10,000 psi of force which appears to cause immediate and significant reduction in shear force. One reason for the technique's effectiveness is the acoustical match between the liquid medium (water) and the meat, which is 70-75% water. Connective tissues and bone seem less affected by the process.

Severe disruption of the muscle ultrastructure might be expected to contribute to enhanced proteolysis and oxidation, creating enhanced tenderness but reduced retail storage life. This research was conducted to determine the effect of the Hydrodyne process on

Table 1. Characteristics of Hydrodyne-treated beef strip loins and top rounds.

	Strip loins - time post-mortem						Top Rounds - time post-mortem					
	d7		d17		d21		d10		d17		d21	
Trait	C[a]	H[a]	C	H	C	H	C	H	C	H	C	H
Shear force, lb	7.12[c]	6.20[d]	5.60[d]	5.84[d]	—	—	—	—	—	—	—	—
TBARS[b]	.36[c]	.34[c]	.20[c]	.21[c]	1.28[d]	.83[d]	.25[c]	.26[c]	.18[c]	.32[c]	1.37[d]	1.48[d]
Aerobic plate count, cfu/in^2	73.2[c]	38.0[c]	52.4[c]	53.4[c]	453.0[d]	124.9[c]	61.9[c]	30.8[c]	50.0[c]	16.9[c]	477.1[c]	71.8[c]
Anaerobic plate count, cfu/in^2	55.7[c]	63.3[c]	14.8[d]	5.3[d]	12.2[d]	5.8[d]	4.1[c]	27.6[d]	8.5[c]	4.2[c]	1.4[c]	4.4[c]

[a]C=Control (untreated); H=Hydrodyne - Treated.
[b]TBARS=Thiobarbituric acid - reactive substances, a measure of rancidity.
[c,d]Means in the same row bearing different superscripts are different (P<.05).

tenderness, oxidative rancidity, color and microbial growth during storage and retail display of beef.

Procedure

Sixteen beef strip loins and 16 rounds (8 Control [C] and 8 Hydrodyne [H] each) were selected, vacuum-packaged and shipped to the Hydrodyne facility (Buena Vista, VA) for testing. Five days postmortem, the meat was placed within the water-filled hemispherical tank. The explosive mixture (ammonium nitrate and nitromethane) was positioned in the water 18 in. from the bottom of the tank and detonated. The resulting shock force was estimated to be 4,000 psi.

All meat was then transported to the Beltsville Agricultural Research Center in Beltsville, Maryland and representative samples were removed, repackaged and shipped on ice to the University of Nebraska, Lincoln, Nebraska. Samples were taken at three different periods: after shipping, after storage and after retail display. Following shipping, strip loins were sampled (day 7), repackaged in vacuum and stored an additional 10 days at 40°F before sampling during the beginning and end of a retail display period. Top rounds were sampled (day 10), packaged and stored an additional 7 days before sampling as previously described. Analysis of pH, purge, thiobarbituric acid-reactive substances (TBARS), aerobic plate count and anaerobic plate count were conducted after a shipping period, at the beginning and at the end of a retail display period (day 7, 17, 21 for strip loins and day 10, 17, 21 for top rounds). Panel discoloration scores (lean color, surface uniformity and surface discoloration) and Hunter colorimeter lab values were obtained for both cuts each day of the retail display period. Warner-Bratzler shear force (day 7, 17) and sarcomere length (day 7) were collected only on strip loins.

For retail display, samples were randomly positioned in the retail case and repositioned each day. Samples were maintained at 40°F with light ranging from 20-50 foot candles. Strip loin steaks were broiled to an internal temperature of 158°F and as many .5- in diameter cores were obtained as possible (8-10 cores). The cores were sheared parallel to the long axis of the muscle fiber. Cooking loss and cooking time were also recorded.

Results

Hydrodyne treatment of the strip loins caused a significant decline in shear force (Table 1) measured two days after treatment (7 days postmortem). This was an immediate and meaningful decline. An extended aging period (17 days postmortem), removed the tenderness benefits of the process (no difference in shear force). It is interesting to note that shear force was generally acceptable in all samples (<7.72 lbs), yet Hydrodyne still proved beneficial. Previous research on the process indicated over-tenderization does not seem to occur and that tough longissimus muscles seem to benefit more from Hydrodyne treatment than tender longissimus muscles. These data suggest aging may allow untreated meat to reach a similar level of tenderness. A study to compare aging time and Hydrodyne treatment is needed to determine the extent to which tenderness benefits of aging supersede the benefits from the Hydrodyne process. Insufficient samples were collected from the top round to permit an assessment of shear force in these muscles.

No differences among the treatments were consistently found in muscle pH, sarcomere length or purge for either cut. All samples exhibited a high amount of purge, probably due to temperature fluctuations during the shipping period. This may have masked any treatment differences.

It was anticipated that Hydrodyne treatment might enhance oxidative rancidity before retail storage. All TBARS (a measure of rancidity) were below 0.4. This is well below 1.0, the point at which rancidity is usually detected. In this study, extended retail display after an extended storage period increased the amount of thiobarbituric acid-reactive substances (Table 1). However, no differences among treatments were revealed for either cut (.34 [H] vs .36 [C] in strip loins, d7 and .26 [H] vs .25 [C] in top rounds, d10). There was a trend for Hydrodyne-treated strip loins to have a lower TBARS readings after extended retail display, but this difference was not consistent enough to be significant (.83 [H] vs 1.28 [C] for the strip loins (P>.05) and 1.48 [H] vs. 1.37 [C] for the top rounds (P>.05). Thus, it appears the Hydrodyne process does not compromise rancidity, which impacts flavor stability.

It should be noted that while microbial numbers were extremely low (<500 cfu/square in), in all cases, the Hydrodyne-treated rounds possessed slightly, but significantly, higher

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numbers of anaerobic microbes after storage and shipping, which did not carry through retail display. Previous research suggested a slight but significant reduction in microbial numbers when the Hydrodyne process was applied. A similar trend noted for aerobic plate count in the strip loin and round samples was attributable to a single sample of each muscle with a much higher count than all other samples, regardless of treatment (Table 1). No credible reason could be found for excluding the data points. As expected, the number of anaerobic micro-organisms declined during retail display. No differences were detected at the initiation or the conclusion of the retail display period.

Lean color, surface uniformity and surface discoloration panel scores revealed no differences among treatments in either cut. Hunter color L* values were higher in the Hydrodyne strip loins and top rounds, indicating Hydrodyne was slightly lighter ($P<.05$) than the control (43.84 [H] vs. 41.70 [C] for the strip loins and 45.34 [H] vs. 44.53 [C] for the top rounds). These data indicate the Hydrodyne process can tenderize unaged meat with no detriment to product display or shelf stability characteristics. Further study on the process is needed to clarify the Hydrodyne/aging relationship and to refine the technique prior to commercialization.

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Dietary Calcium and Phosphorous: Relationship to Beef Tenderness and Carcass Maturity

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Dietary levels of calcium and phosphorous for finishing cattle have no effect on overall maturity scores and tenderness of beef.

Summary

The effect of dietary mineral status as related to carcass maturity or meat tenderness was studied. Finishing yearling steers were individually fed varying levels of calcium and phosphorous. Neither mineral was significantly related to overall carcass maturity scores or meat tenderness. When fed at the levels in this trial, it appears there are no adverse effects of dietary calcium and phosphorous on carcass or meat characteristics.

Introduction

Beef carcass maturity is determined by visually assessing lean color and the degree of ossification (conversion of cartilage to bone) in the skeleton. Younger animals (about 9-30 months of age) usually possess characteristics of "A" maturity. Maturity classification is important, as advancing maturity is often associated with a decline in meat tenderness. Recent changes in the USDA quality grades for beef impose a strict penalty for carcasses which possess small or slight amounts of marbling and "B" maturity (the next classification after "A" in the quality grading system). Carcasses, which would formerly have qualified for Choice and Select grades now qualify only for Standard grade. Accordingly, it is important to determine factors which influence physiological maturity and ossification. Current speculation suggests mineral status may play a role in the ossification rate, meaning younger animals with improper mineral status might be classified as older than "A" maturity, with a subsequent loss of value. This project was conducted to assess the relative significance of dietary Ca and P on maturity scores and beef tenderness.

Procedure

Sixty yearling crossbred steers were individually fed once daily from September 4 to December 18, 1996 (105 d). Steers were randomly assigned one of 10 treatments, consisting of two levels of calcium (Ca), either 0.35 or 0.70 % of the dietary DM, with limestone as the

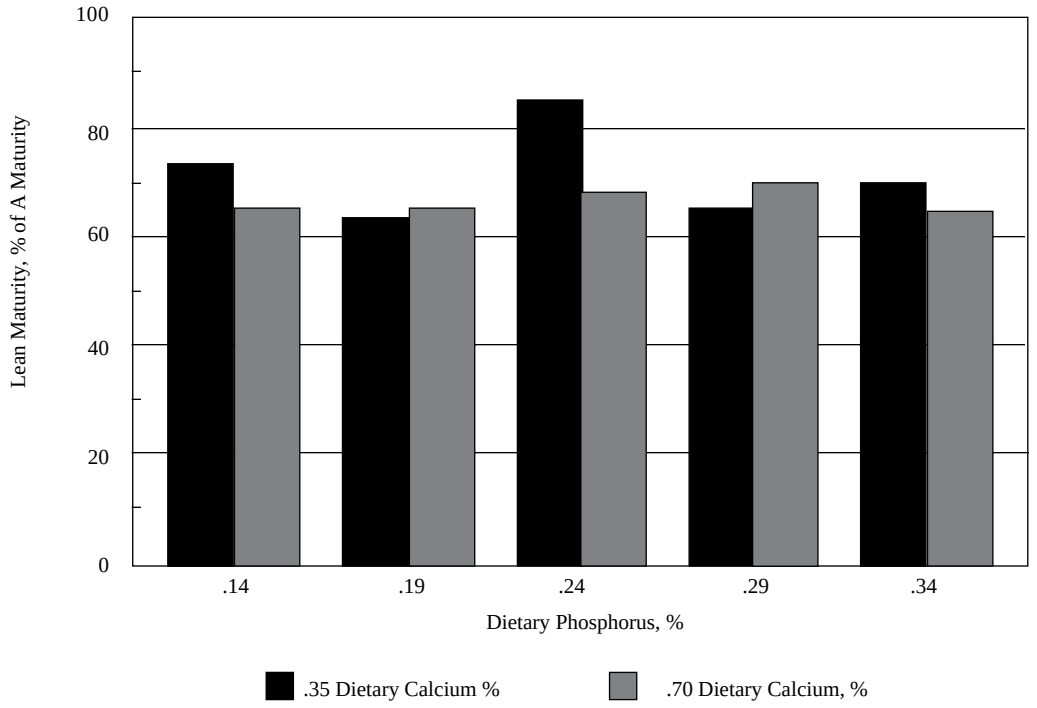

Figure 1. Dietary mineral level and beef lean maturity.

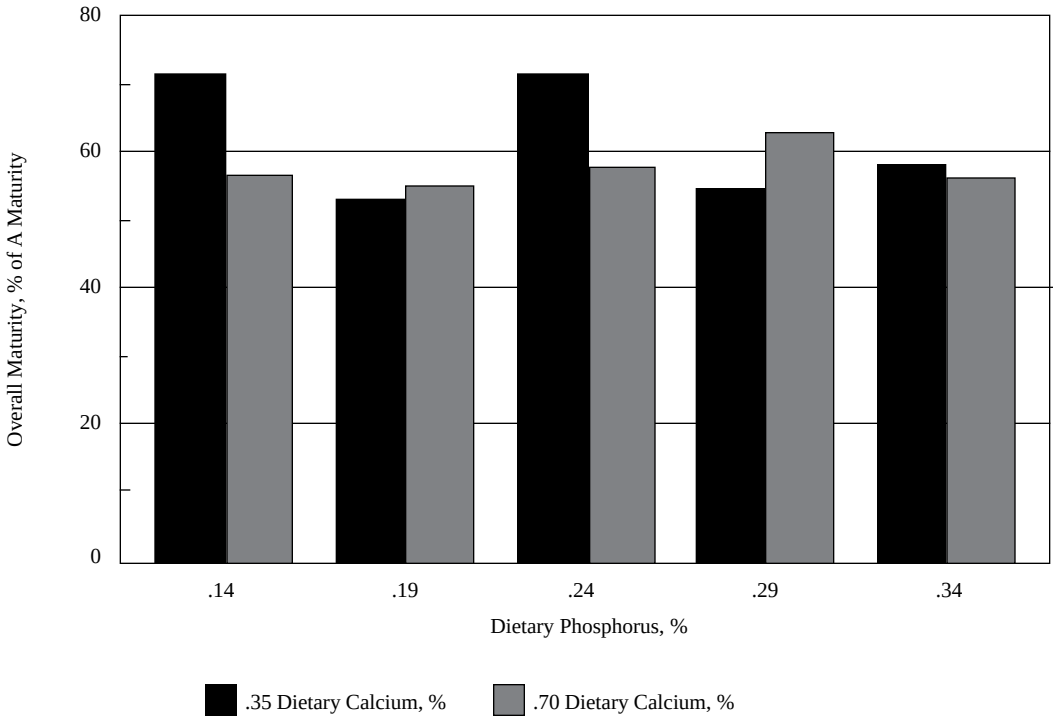

Figure 2. Dietary mineral level and beef overall maturity.

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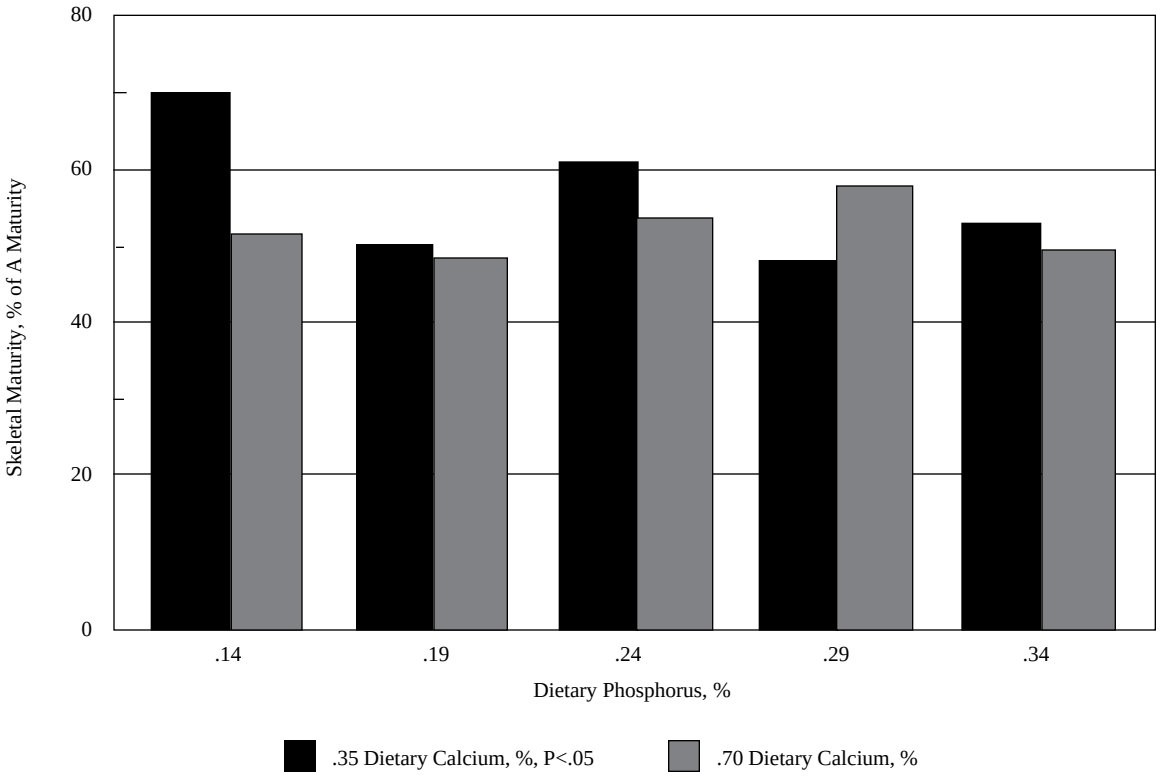

Figure 3. Dietary mineral level and beef skeletal maturity.

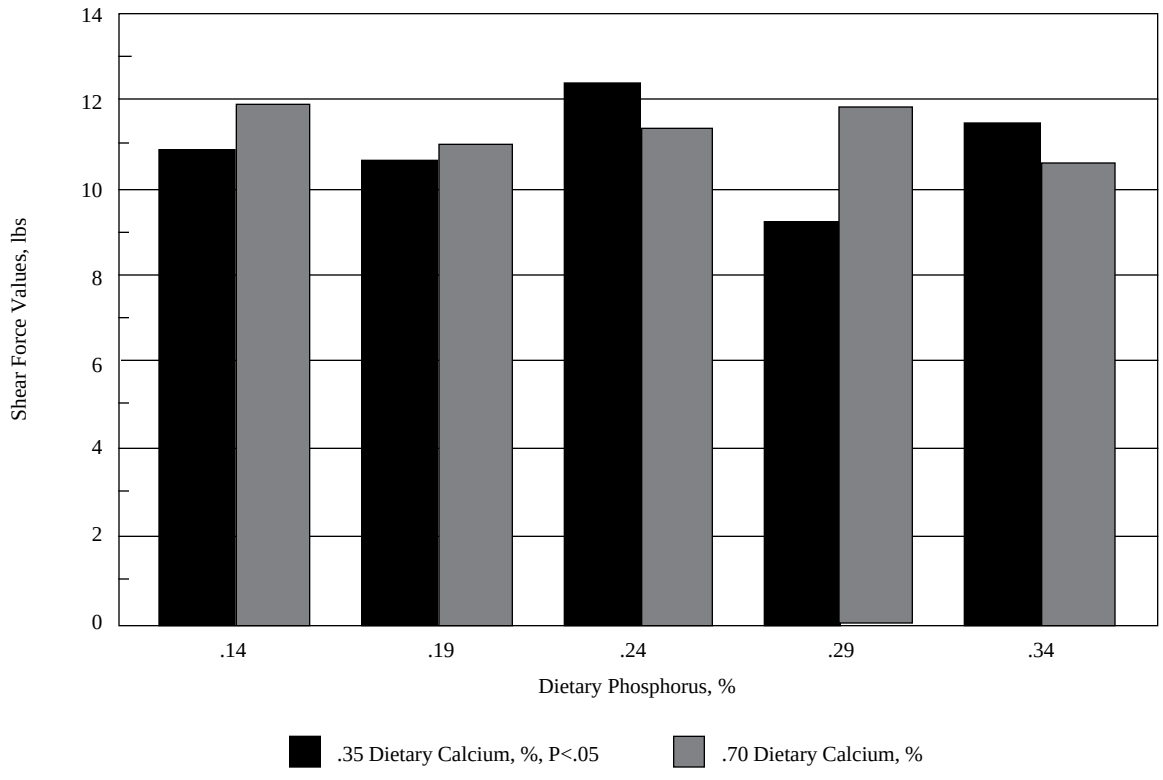

Figure 4. Dietary mineral level and beef tenderness.

source of supplemental Ca. Within each Ca level, there were five levels of phosphorous (P): 0.14, 0.19, 0.24, 0.29 or 0.34% of dietary DM. Supplemental P was provided by mono-sodium phosphate (NaP). Diets during this trial were formulated for 12% protein. Cattle were also implanted with Revalor-S® at the start of the trial.

Carcass data (lean maturity, skeletal maturity, overall maturity and marbling score) were assessed by a Federal USDA Meat Grader and recorded at the meat plant. Wholesale rib sections (IMPS 122A) were shipped to the University of Nebraska, aged for 7 days, then frozen. A one-inch thick steak was removed for tenderness assessment. Thawed steaks were cooked on a Farberware Open Hearth broiler to an internal temperature of 158°F, cooled to about 70°F, and 8-10 cores (1/2 inch in diameter) were removed parallel to fiber direction. The cores were then sheared using a Warner-Bratzler shear attachment to an Instron Universal Testing Machine.

The analysis of variance included Ca and P as main effects. Significant ($P < .05$) interactions were separated using contrasts to test for linearity.

Results

Dietary levels of Ca and P had no effect on either lean maturity or overall maturity scores (Figures 1 and 2). This was to be expected, as there is little information that suggests Ca or P would affect meat color. Given the slight effect on skeletal maturity and no effect on lean color, it was expected there would be no effect on overall maturity because of dietary Ca and P levels.

Figure 3 graphically depicts the relationship of dietary mineral level and beef skeletal maturity. At 0.35% dietary Ca, skeletal maturity score decreased in a linear relationship ($P < .05$) with an increase in dietary phosphorous. Higher levels of dietary P might be expected to cause an increase in ossification, as Ca and P act synergistically to form bone. However, the magnitude of the skeletal maturity difference was slight (A 70 to A 48). While a significant relationship did exist, the effect on skeletal maturity was minimal. Changing diet formulations to garner this response may not be merited. The relationship was not significant at the 0.70% Ca level. In related work, Erickson et al. (1998 Nebraska Beef Cattle Report, pp. 78) found no difference in animal gain or bone strength from the cattle used in this trial.

No significant correlations were found linking tenderness to skeletal or overall maturity. The range in cattle age in the study may have been insufficient to detect the overall relationship. Lean maturity scores were related ($r = .29$, $P < .05$) to shear force.

No significant relationships were found among mineral levels and meat tenderness (Figure 4). These data indicate Ca and P, at the levels used in this study, are not responsible for maturity or tenderness changes in beef.

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